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(54) Synchronization detection device and method in DS-CDMA

(57) In a synchronization detection device and its method, codes to be detected can be identified at high speed. the supply of the data shift clock (D_{CLK1}) to be given to the matched filtering means (82) is stopped at desired timing to hold the received signal (S10) and replica code generated at the correlation coefficient generation means (83) is switched -to the first, second or third replica code at desired timing to detect the correlation value of that time. Thereby, the second code, the third code and the first code are detected in order to detect the timing and the code type of the first code. Therefore, each correlation detection can be conducted at the same timing since the matched filtering means conducts the correlation detection at high speed holding the received signal and thus, the first code included in the received signal can be identified at higher speed than before.

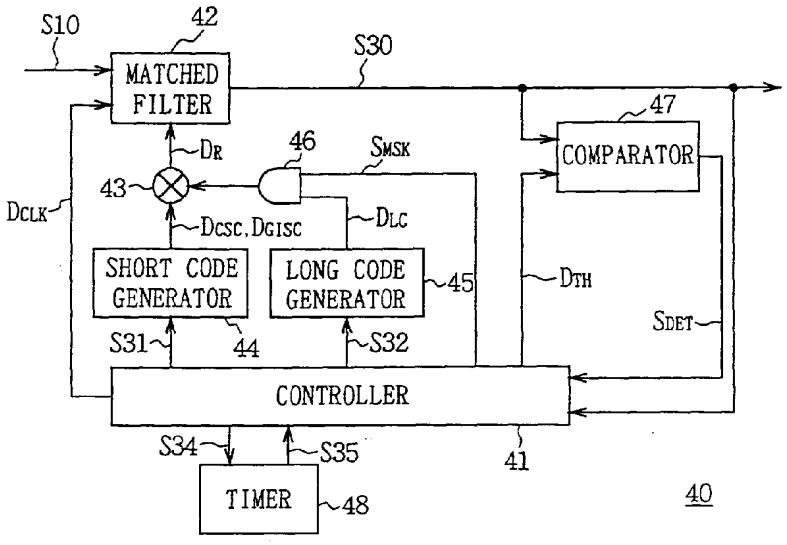

FIG. 5

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Description

[0001] This invention relates to a synchronization detection device and its method, and more particularly, is suitably applied to a cellular radio communication system that allows asynchronous communication between base stations according to the direct sequence-code division multiple access (DS-CDMA) system.

[0002] The DS-CDMA system is a multiplexing system using spread codes and its application to the cellular radio communication system has been vigorously under study as one of the radio access systems of the future mobile communication system. In the cellular radio communication system, an area to provide communication service is divided into cells with a desired size and a base station as a fixed station is provided in each cell and a communication terminal device which is a mobile station is connected by radio to the base station having the best communication state.

[0003] In such cellular radio communication system, a method to search a base station to which the mobile station is connected is generally called as a cell search. In this DS-CDMA cellular radio communication system, in order that the base stations use the same frequency, timing of spread code included in the received signal should be trapped simultaneously with this cell searching.

[0004] This cellular radio communication system using the DS-CDMA system can be classified into two types: a synchronous system between base stations in which temporal synchronization is performed among all base stations; and asynchronous system between base stations in which time synchronization is not conducted. Since the synchronous system between base stations is regulated by the IS-95 Standard, absolute reference time is set in each base station using radio waves of the global positioning system (GPS) and thus, temporal synchronization will be performed among base stations. In this system, base stations transmit the same long code as the spread code at timing different from each other based on the absolute reference time. And thus, at the time of cell search, the mobile station can search the base station to be connected only by trapping the timing of long code.

[0005] On the other hand, in the asynchronous system between base stations, base stations transmit a different long code in order to identify base stations, and accordingly, at the time of cell search, it is necessary for the mobile station to detect timing of the long code as well as the type of the long code. Therefore, in the case of asynchronous system between base stations, there is a demerit that the time required for cell search becomes longer as compared with the synchronous system between base stations. However, as contrary to the above, in the asynchronous system between base station, since it is unnecessary to receive GPS radio wave, service area can be widened to areas where GPS radio wave can not reach. Therefore, if the cell search problem can be solved, this system is very effective.

[0006] As a method to speed up the cell search in the asynchronous system between base stations, several methods can be considered. One of these methods is that of transmitting a common short code among base station as well as a long code and a group identification short code to specify the long code group, and of detecting the timing and code type of the long code to be transmitted based on these short codes. In the following explanations, the method to detect the code timing and code type will be referred to as identification.

[0007] More specifically, the base station has a signal generation unit 1 of the control channel as shown in Fig. 1, and it forms transmission data in which long code, common short code and group identification short code are combined by using the signal generation unit 1, and transmits this through the control channel. At first, a first multiplier 2 sequentially spreads input information bit S1 having the value such as "1" with the common short code CSC having comparatively short cycle, that is common in each base station, and outputs spread data S2 to a second multiplier 3. In the second multiplier 3, long code LC having the longer cycle than the common short code CSC is entered and the spread data S2 is successively spread using the long code LC and the spread data S3 is output to an adder 5.

[0008] In this connection, this long code LC is very specific to every base station and base stations are identified by this long code LC. And a long code enable signal SCE is entered into AND circuit 4, and by setting this long code enable signal LCE to the level "L" at a fixed cycle, the long code LC to be supplied to the second multiplier 3 will be masked over the segment of level "L". Thus, the spread data S3 to be sent from the second multiplier 3 is not spread out in the long code LC over the segment on which long code enable signal LCE has the level "L". Hereinafter, the segment over which the long code LC is masked is referred to as masked segment.

[0009] On the other hand, group identification short code GISC, that shows the group of long codes LC to be used in the signal generation unit 1 and has the same cycle as the common short code CSC, is entered into the third multiplier 6. And this third multiplier 6 spreads out information bit S4 having such as the value "1" with this group identification short code GISC and outputs spread data S5 to the adder 5. In this connection, the spread data S5 will be formed on the masked segment of long code LC.

[0010] The adder 5, by adding these spread data S3 and S5, forms transmission data S6 for transmitting by the control channel. Thus, by transmitting this transmission data S6 by the control channel via the transmission circuit and antenna (not shown in Fig.), the transmission signal containing long code LC, common short code CSC and group identification short code GISC is be transmitted from the base station.

[0011] At this point, the timing of long code LC, common short code CSC and group identification short code GISC included in the transmission signal transmitted from the base station will be shown in Figs. 2A to 2C. As shown in Figs.

2A to 2C, common short codes CSC exist repeatedly in the transmission signal. Also long codes LC exist repeatedly in the transmission signal. However, the long code LC is masked just over the segment synchronized with the common short code CSC at the cycle T_{MK}. Moreover, in the masked segment of the long code LC, since the spread data S5 is added, group identification short code GISC exists over that masked segment.

[0012] In the case of receiving the transmission signal containing codes (CSC, GISC and LC) by the mobile station at the above timing and identifying the long code LC included in the transmission signal, firstly the common short code CSC existing over the masked segment is detected from the received signal to detect the timing of long code LC. When it is detected, the type of group identification short code GISC existing over the masked segment is determined. In this case, the group identification short code GISC shows the group of long code LC included in the received signal, and if the type of group identification short code GISC can be identified, the candidate of long code LC can be specified to that group.

[0013] Accordingly, after the grup identification short code GISC is determined, the type of long code LC included in the received signal can be identified by narrowing down the candidate onto the long code LC in the group which the group identification short code GISC shows and sequentially confirming whether these are candidates or not. With this arrangement, since the number of candidates can be decreased by the group identification short code GISC, the time required to judge the type of long code LC can be shortened as compared with the case of making all long codes LC as candidates.

[0014] At this point, the synchronization detection device to identify long code LC included in the received signal according to the above method will be shown in Fig. 3. In this Fig. 3, 10 generally shows a synchronization detection device to be provided in the mobile station, receiving the received signal S10 received via an antenna and a receiver (not shown in Fig.), and as well as detecting the timing of long code LC having the strongest signal level included in the received signal S10, it determines the type of that long code LC. More specifically, at the time of cell search, this judges the base station by determining the timing and code type of the long code LC having the strongest signal level.

[0015] At first, the matched filter 11 detects the correlation values between the received signal S10 and the replica code D_{CSC} of the common short code CSC generated at the short code generator 12 in succession and stores the correlation value data S11 in a memory 13. The matched filter 11 detects the correlation value at least over the period of approximately three cycles of long code cycle.

[0016] The maximum correlation detection circuit 14 reads out the correlation value data S11 stored in the memory 13 and detects the data having the largest correlation value among the data S11. And assuming the timing at which the largest correlation value is obtained as the timing of long code LC having the strongest signal level included in the received signal S10, the maximum correlation detection circuit 14 outputs timing information S12 showing that timing. This timing information S12 is transmitted to the short code generator 12 and the long code generator 15 as the timing information S12 to generate replica code of the group identification short code GISC and replica code of the long code LC. Moreover, the maximum correlation detection circuit 14 outputs the detected correlation value data S13 having the largest value to a threshold determining circuit 18.

[0017] When the short code generator 12 receives the timing information S12, it generates replica code D_{GISC}, that is the first candidate in the plural number of group identification short codes GISC at the timing shown by the timing information S12 and outputs the code D_{GISC} is to a sliding correlator 17 via a multiplier 16.

[0018] On the other hand, the threshold determining circuit 18 determines the first threshold value for determining the type of group identification short code GISC and the second threshold value to determine the type of long code LC based on the correlation value data S13 and outputs these to a judging unit 19 as the threshold data S14.

[0019] The sliding correlator 17 successively multiplies the replica code D_{GISC} of the group identification short code GISC by the input received signal S10 and by integrating the multiplication result for 1 cycle of the replica code D_{GISC}, calculates the correlation value and outputs the correlation value data S15 to the judging unit 19.

[0020] The judging unit 19 judges whether the correlation data S15 transmitted from the sliding correlator 17 exceeds the first threshold value or not, and if it does not exceed the first threshold value, outputting the control signal S16 to the short code generator 12, causes this short code generator 12 to generate replica code D_{GISC}, that is the next candidate of the group identification short code GISC. Thus, the replica code D_{GISC} of the group identification short code GISC is be generated by the short code generator 12 in succession and the correlation value data S15 of that replica code D_{GISC} is obtained successively by the sliding correlator 17.

[0021] On the contrary, if the correlation value data S15 transmitted from the sliding correlator 17 exceeds the first threshold value, the judging unit 19 judges that the then replica code D_{GISC} is the group identification short code GISC showing the group of long codes LC to be detected and outputs the group shown by that group identification short code GISC to the long code generator 15 as group information S17. Also, in the case where the correlation value data S15 exceeds the first threshold value, the judging unit 19 outputs a control signal S18 to the short code generator 12 and causes the short code generator 12 to generate replica code D_{CSC} of the common short code CSC.

[0022] When the long code generator 15 receives the group information S17, it generates replica code D_{LC} that is the first candidate of the long code LC in the group which the group information S17 shows at the timing shown by

timing information S12. This replica code D_{LC} of the long code LC is entered into the sliding correlator 17 after being multiplied by replica code D_{CSC} of the common short code CSC in the multiplier 16.

[0023] The sliding correlator 17 successively multiplies the input received signal S10 by the replica code D_{LC} of the long code LC which has been multiplied by the replica code D_{CSC} of the common short code CSC and by integrating the multiplication result for 1 cycle of replica code D_{LC}, calculates the correlation value and outputs the correlation value data S19 to the judging unit 19.

[0024] The judging unit 19 judges whether the correlation value data S19 output from the sliding correlator 17 exceeds the second threshold value or not, and if it does not exceed, outputting a control signal S20 to the long code generator 15, causes this to generate the next candidate of the long code LC, i.e., replica code D_{LC}. Thus, the judging unit 19 causes the long code generator 15 to generate replica code D_{LC} of the long code LC in succession and obtains the correlation value data S19 of that replica code D_{LC} by the sliding correlator 17.

[0025] On the contrary, in the case where the correlation value data S19 to be sent out from the sliding correlator 17 exceeds the second threshold value, the judging unit 19 judges that the then replica code D_{LC} as the long code LC to be detected and outputs information S21 showing the type of the long code LC. Accordingly, this synchronization detection device 10, at the first stage, by detecting the common short code CSC, detects the timing of the long code LC having the strongest signal level in the received signal. At the following second stage, the judging unit 19 identifies the group identification short code GISC included in the received signal to detect the group of long code LC to be detected, and at the third stage, it determines the type of long code LC by making the long code LC in that group as a candidate. Thus, in this synchronization detection device 10, the long code LC having the strongest signal level included in the received signal can be identified.

[0026] At this point, the construction of matched filter 11 for detecting the correlation value of the common short code CSC shown in Fig. 3 will be shown in Fig. 4. Since generally the received signal S10 is the quadrature-phase-shift-keying (QPSK)-modulated, in practice the matched filter 11 has the 4-phase construction as shown in this Fig. 4. Firstly, in the matched filter 11, the received signal S10 is entered into multipliers 20 and 21. In the multiplier 20, carrier signal S26, which is generated by delaying the carrier signal S25 generated in the oscillator 22 by $\pi/2$ with the phase-shifter 23, is entered. The multiplier 20, by multiplying this carrier signal S26 by the received signal S10, takes out signal element SI of the in-phase element I in the received signal S10. This signal element SI of the in-phase element I, after its unnecessary element is eliminated through the low-pass filter 24, is entered into an analog-to-digital converter 25 to be converted to digital in-phase data U_I.

[0027] On the other hand, the carrier signal S25 generated in the oscillator 22 is entered into the multiplier 21. The multiplier 21, by multiplying the carrier signal S25 by the received signal S10, takes out a signal element SQ of the quadrature element Q included in the received signal S10. This signal element SQ of the quadrature element Q, after its unnecessary element is eliminated through the low-pass filter 24, will be entered into an analog-to-digital converter 27 and digital conversion is applied here and converted to digital quadrature data U_Q.

[0028] Correlators 28 to 31 are matched filters for detecting the correlation value per each signal element. Of replica code D_{CSC} of the common short code CSC to be transmitted from the short code generator 22, the in-phase data U_I and the replica code U_{IR} of in-phase element are entered into the correlator 28 and the correlator 28 calculates the correlation value U_{II} ($= U_I * U_{IR}$) between the in-phase data U_I and the in-phase element replica code U_{IR}, and outputs this to an adder 32.

[0029] Furthermore, in the correlator 29, the in-phase data UI and the orthogonal element replica code U_{QR} of replica code D_{CSC} of the common short code CSC to be transmitted from the short code generator 12 are entered. The correlator 29 calculates the correlation value U_{IQ} ($= U_I * U_{QR}$) between the in-phase data U_I and the quadrature element replica code U_{QR} and outputs this to a differentiator 33.

[0030] Similarly, in the correlator 30, the above-mentioned quadrature data U_Q and the replica code U_{QR} of the quadrature element are entered. The correlator 30 calculates the correlation value U_{QQ} ($= U_Q * U_{QR}$) between the quadrature data U_Q and quadrature element replica code U_{QR}, and outputs this to the adder 32. Moreover the above-mentioned quadrature data U_Q and the in-phase element replica code U_{IR} are entered in the correlator 31 to calculate the correlation value U_{QI} ($= U_Q * U_{IR}$) between the quadrature data U_Q and the in-phase element replica code U_{IR} and output this to the differentiator 33.

[0031] The adder 32 adds up the correlation value U_{II} and the correlation value U_{QQ} and outputs the addition resultant to a square-law circuit 34. On the other hand, the differentiator 33 calculates the difference between the correlation value U_{QI} and the correlation value U_{IQ} and outputs the differential result to a square-law circuit 35. Thus, the addition result and the differential result are squared by square-law circuits 34 and 35 respectively and by adding the squared result by an adder 36, finally the correlation value data S11 ($=(U_{II} + U_{QQ})^2 + (U_{QI} - U_{IQ})^2$) to the replica code D_{CSC} is calculated.

[0032] According to the identification method of long code LC as described above, the timing detection processing of long code LC using the common short code CSC, the group identification processing of long code LC using the group identification short code GISC and the identification processing of long code LC focussing the candidate onto

the identified group are conducted in time series using the matched filter and the sliding correlator, and basically each processing is conducted at different timing. When the condition of transmission path changes due to such as fading, there is the possibility that the long code LC cannot be identified. Thus, according to the identification method described above, this possibility is avoided by extending the identification period of the long code LC such as detecting the correlation values of the overall long codes LC, but it causes the inconvenience of taking time when identifying long codes LC.

[0033] In view of the foregoing, an object of this invention is to provide a synchronization detection device which can accurately identify codes to be detected at high speed and can minimize the circuits.

[0034] The foregoing object and other objects of the invention have been achieved by the provision of a synchronization detection device for receiving a signal containing the first code, the known second code to detect the timing of the first code and the third code to specify the group of the first code and for detecting the timing and code type of the first code included in the received signal. The synchronization detection device comprises a matched filtering means for receiving the first, the second or the third replica code corresponding to the first, the second or the third code and detecting the correlation value between the first, the second or the third replica code and the received signal as well as capturing the received signal based on the data shift clock to be supplied, a correlation coefficient generation means for generating the first, the second or the third replica code and supplying it to the matched filtering means, and a control means for, as well as stopping the supply of data shift clock at the desired timing and causing the matched filtering means to hold the received signal, switching the replica code to be generated at the correlation coefficient generation means to the first, the second or the third replica code at desired timing and detecting the then correlation value, and thereby detecting the second code, the third code and the first code successively and detecting the timing and code type of the first code.

[0035] Thus, the data shift clock to be given to the matched filtering means is stopped at desired timing and the received signal is held, and the replica code generated at the correlation coefficient generation means is switched to the first, the second or the third replica code at desired timing to detect the then correlation value. Thereby, the second code, the third code and the first code are successively detected and the timing and code type of the first code are detected. Therefore, the matched filtering means can conduct the correlation detection at high speed holding the received signal and each correlation detection can be conducted at approximately the same timing, and thereby the first code included in the received signal can be identified at high speed as compared with the conventional device.

[0036] The nature, principle and utility of the invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram showing the signal forming unit of the control channel provided in the base station;
Figs. 2A to 2C are brief linear diagrams showing the construction of each code in the received signal to be transmitted from the base station;
Fig. 3 is a block diagram showing the construction of a conventional synchronization detection device;
Fig. 4 is a block diagram showing the construction of a conventional 4-phase matched filter;
Fig. 5 is a block diagram showing the construction of a synchronization detection device according to the first embodiment;
Fig. 6 is a conceptual block diagram showing the internal construction of the matched filter;
Fig. 7 is a brief linear diagrams showing the construction of each code in the received signal and the detection timing of correlation values to each code;
Fig. 8 is a flow chart showing the processing procedure up to the group identification in the first embodiment;
Fig. 9 is a flow chart showing the processing procedure up to the long code identification in the first embodiment;
Fig. 10 is a block diagram showing the construction of a short code correlation detection device according to the first embodiment;
Figs. 11A to 11F are timing charts explaining the correlation value calculation timing according to the first embodiment;
Fig. 12 is a block diagram showing the construction of a four-phase matched filter according to the first embodiment;
Figs. 13A to 13I are timing charts explaining the correlation value calculation timing according to the first embodiment;
Fig. 14 is a block diagram showing the construction of synchronization detection device according to the second embodiment;
Fig. 15 is a block diagram showing the construction of a correlation coefficient generator according to the second embodiment;
Fig. 16 is a block diagram explaining a general PN decoder;
Fig. 17 is a block diagram explaining a PN decoder according to the present invention;
Fig. 18 is a block diagram explaining a data decoder according to the present invention;
Fig. 19 is a flow chart showing the processing procedure up to the group identification according to the second

embodiment;

Fig. 20 is a flow chart showing the processing procedure up to the long code identification according to the second embodiment; and

Figs. 21A to 21C are timing charts explaining the detection timing up to the group identification.

[0037] In Fig. 5, 40 generally shows a synchronization detection device according to the first embodiment, and by controlling each circuit block with a controller 41, identifies the long code LC included in the received signal S10 at high speed. In this case, it is supposed that the long code LC, common short code CSC and group identification short code GISC are included in the received signal S10 at the timing shown in Figs. 2A to 2C.

[0038] Firstly, as shown in Fig. 6, a matched filter 42 comprises the same number of stages of shift registers 42A as the number of chips of common short codes CSC, coefficient multiplier 42B having the same number of multipliers as the number of stages of the shift registers 42A, and a combining circuit 42C for combining the multiplication results to be transmitted from the multipliers of the coefficient multiplier 42B, in which a bit string of received signal S10 is sequentially input to the shift register 42A. Also the shift register 52A receives the operation clock DCLK from the controller 41 and sequentially shifts the bits of the received signal S10 based on this operation clock D_{CLK}.

[0039] Moreover, the matched filter 42 enters each bit of the replica code D_R to be supplied via the multiplier 43 to each multiplier of the coefficient multiplier 42B one by one, and multiplies each bit to be sent from each register of the shift register 42A by each bit of replica code DR with the coefficient multiplier 42B. Thus, in the matched filter 42, by combining the multiplication result to be transmitted from each multiplier of the coefficient multiplier 42B with the combining circuit 42C, the correlation value S30 is obtained and the resultant correlation value S30 will be transmitted.

[0040] The short code generator 44 is a circuit to generate a replica code D_{CSC} of the common short code CSC or a replica code D_{GISC} of the group identification short code GISC, and generates either the replica code D_{CSC} or D_{GISC} based on the control signal S31 to be transmitted from the controller 41. This replica code D_{CSC} or D_{GISC} is entered into the matched filter 42 via the multiplier 43 as a replica code D_R to be correlation-detected.

[0041] On the other hand, the long code generator 45 is a circuit to generate a replica code D_{LC} of the long code LC, in which the replica code D_{LC} is generated based on the control signal S32 sent from the controller 41 and is output to the AND circuit 46. A mask control signal S_{MSK} is supplied to the other end of input terminal of the AND circuit 46, and thus, only when the level of the mask control signal S_{MSK} is "H", the replica code D_{LC} is sent out from the AND circuit 46. In the case where the replica code D_{LC} is sent out from the AND circuit 46, the replica code D_{LC} is entered into the multiplier 43 and after being multiplied by the replica code D_{CSC} or D_{GISC}, is entered into the matched filter 42 as a replica code D_R to be detected.

[0042] The comparator 47, receiving threshold data D_{TH} from the controller 41, compares the value of this threshold data D_{TH} and the value of correlation value S30 transmitted from the matched filter 42. And as a result, if the correlation value S30 exceeds the value of threshold data DTH, the comparator 47 outputs the detection data S_{DET} to the controller 41. The controller 41 outputs a desired threshold value, out of threshold values V_{TH1} to V_{TH3} memorized inside and the threshold value V_{TH4} determined by the correlation value S30, to the comparator 47 as threshold data D_{TH}.

[0043] As shown in Fig. 7, the timer 48 is a device for counting time to input the received signal S10 only for the length of one cycle T1 of the common short code CSC after identifying the group identification short code GISC, and when the timer 48 receives a count start command S34 from the controller 41, starts the counting operation and after counting the time by the length T1. When the timer 48 counts up to time for the length T1, it outputs count end information S35 to the controller 41. The reason for using the timer 48 to partially input the received signal S10 conducting the counting operation is that the long code LC is identified by the partial correlation and the time to reach the identification is shortened.

[0044] At this point, in this synchronization detection device 40, the processing procedures for identifying the long code LC included in the received signal S10 will be shown in Figs. 8 and 9. Fig. 8 shows processing from the timing detection of long code LC by the common short code CSC to the identification of the group identification short code GISC, and Fig. 9 shows processing from the group identification by the group identification short code GISC to the identification of the long code LC.

[0045] As shown in Fig. 8, in the case of identifying the group of long code LC, the controller 41 makes the short code generator 44 generate the replica code D_{CSC} of the common short code CSC by outputting the control signal S31 at the step SP2 following the step SP1. Then, at the following step SP3, the controller 41 set the first threshold value V_{TH1} for detecting the common short code CSC to the comparator 47.

[0046] Then, at the following step SP4, the controller 41, by supplying the operation clock D_{CLK} to the matched filter 42, releases the hold state of the matched filter 42 and makes the matched filter 42 start the correlation value calculation operation. At the next step SP5, the controller 41 judges whether the correlation value S30 transmitted from the matched filter 42 exceeds the first threshold value V_{TH1} or not. More specifically, in this case, the comparator 47 compares the correlation value S30 with the first threshold value V_{TH1}, and if the correlation value S30 exceeds the first threshold value V_{TH1}, outputs detection data S_{DET}, so that the controller 41 conducts this judgment based on whether this de-

tection data S_{DET} is obtained or not.

[0047] As a result of judgment in this step SP5, if the correlation value S30 exceeds the first threshold value V_{TH1}, the controller 41 moves to the following step SP6 assuming that the common short code CSC has been detected. At the step SP6, the controller 41 stops bit shift operation of the shift register 42A of the matched filter 42 by stopping the operation clock D_{CLK} to be supplied to the matched filter 42. With this arrangement, the controller 41 holds the received signal S10 of the time when the common short code CSC is detected in the shift register 42A.

[0048] At the following step SP7, the controller 41 sets the second threshold value V_{TH2} for detecting the group identification short code GIS to the comparator 47. Then at the next step SP8, the controller 41 causes the short code generator 44 to generate the first candidate of the replica code D_{GISC} out of the plurality of group identification short codes GIS by outputting the control signal S31. Then, the matched filter 42 calculates the correlation value between the received signal S10 presently kept in the shift register 42A and the replica code D_{GISC}.

[0049] At the next step SP9, the controller 41 judges whether the correlation value S30 sent from the matched filter 42 exceeds the second threshold value V_{TH2} or not in the same manner as the judgment processing at the step SP5. As a result, if the correlation value S30 does not exceed the second threshold value V_{TH2}, the controller 41 moves to the step SP10 and causes the short code generator 44 to generates the next candidate of the group identification short code GISC, replica code D_{GISC}, and returning to the step SP9 again, conducts the judgment on the correlation value S30. Accordingly, as a result of generating the candidates of group identification short code GISC successively and judging the correlation values S30, if the correlation value S30 exceeds the second threshold value V_{TH2}, the controller 41 moves to the step SP11 and terminates the processing assuming that the group identification short code GISC could be identified. As a matter of course, the replica code D_{GISC} which could be obtained an affirmative result at the step SP9, becomes group identification short code GISC existing in the received signal S10. Moreover, if the group identification short code GISC can be detected, since the position in which the group identification short code GISC is inserted with respect to the long code LC is already known, this means that the timing of long code LC can be identified. Moreover, since the group identification short code GISC could be identified, this means that the type of long code LC in the received signal S10 could be specified to the group which the group identification short code GISC shows.

[0050] In this connection, Fig. 7D and Fig. 7E show the correlation detection timing of short codes. The correlation value S30 of the replica code D_{CSC} becomes large when the common short code CSC existing over the masked segment is captured in the shift register 42A of the matched filter 42, and at that timing the correlation value S30 exceeding the first threshold value V_{TH1} can be obtained. In this case, since the received signal S10 in which common short code CSC is detected is held in the matched filter 42 and replica codes D_{GISC} to be given to the coefficient multiplier circuit 42B of the matched filter 42 are shifted in order of candidate at high speed, the correlation value S30 of replica code D_{GISC} can be detected at almost the same timing as the correlation value S30 with respect to the common short code CSC.

[0051] Then, referring to Fig. 9, the processing up to the identification of long code LC will be explained. Provided that in this Fig. 9, the group identification short code GISC could be detected by the processing shown in Fig. 8, and the long code LC will be identified using this group identification short code GISC when intermittently receiving signal. As shown in this Fig. 9, at the step SP21 following the step SP20, the controller 41, outputting the control signal S31, causes the short code generator 44 to generate replica code D_{GISC} of the group identification short code GIS detected earlier. At the following step SP22, the controller 41 sets the third threshold value V_{TH3} for detecting that group identification short code GISC to the comparator 47.

[0052] At the following step SP23, the controller 41 releases the hold state of the matched filter 42 by supplying the operation clock D_{CLK} to the matched filter 42 and makes the matched filter 42 start the correlation value calculation operation. Then, at the next step SP24, the controller 41 judges whether the correlation value S30 transmitted from the matched filter 42 exceeds the third threshold value V_{TH3} or not based on the detection data D_{DET} to be sent from the comparator 47.

[0053] As a result of this judgment, when the correlation value S30 exceeds the third threshold value V_{TH3}, the controller 41 moves to the following step SP25 supposing that the group identification short code GISC can be detected. At the step SP25, the controller 41 outputs a count start command S34 and causes the timer 48 to count up to time T1. This time T1 represents the time to capture the received signal S10 required for taking partial correlation with respect to the replica code D_{LC} of the long code LC.

[0054] At the following step SP26, the controller 41 judges whether the time T1 has elapsed or not based on count stop information S35, and if yes, moves to the next step SP27. At the step SP27, the controller 41 stops the bit shift operation of the shift register 42A of the matched filter 42 by stopping the supply of operation clock D_{CLK} to the matched filter 42 and causes it to hold data currently existing in the shift register 42A.

[0055] At the following step SP28 the controller 41 calculates the fourth threshold value V_{TH4} for detecting the long code LC based on the correlation value S30 of the time when the group identification short code GISC was detected and sets this fourth threshold value V_{TH4} to the comparator 47. At the next step SP29, the controller 41, outputting the control signal S31 to the short code generator 44, causes the short code generator 44 to generate the replica code

D_{CSC} of the common short code CSC. At the next step SP30, the controller 41 causes the the long code generator 45 to generate the first candidate of the long code LC, the replica code D_{LC}, by outputting the control signal S32 to the long code generator 45. Then, at the next step SP31, the controller 41, by switching the mask control signal S_{MSK} to the level "H" outputs the replica code D_{LC} generated at the long code generator 45 to the multiplier 43. Then, the replica code D_R, which is obtained by multiplying the replica code D_{CSC} of the common short code CSC by the replica code D_{LC} of the long code LC, is supplied to the matched filter 42. Thus, the matched filter 42 calculates the correlation value between this replica code DR and the received signal S10 currently existing in the shift register 42A.

[0056] At the following step SP32, the controller 41 judges whether the correlation value S30 transmitted from the matched filter 42 exceeds the fourth threshold value V_{TH4} or not based on the detection data S_{DET} from the comparator 47. As a result, if the correlation value S30 has not exceeded the fourth threshold value V_{TH4}, the controller 41 proceeds to the step SP23 and causes the long code generator 45 to generate the next candidate of the long code LC, replica code D_{LC}, and returning to the step SP32, conducts the judgment on the correlation value S30. As a result of sequentially generating candidates of the long code LC and judging the correlation value S30, when the correlation value S30 exceeds the fourth threshold value V_{TH4}, the controller 41 moves to the step SP34 and terminates the processing assuming that the long code LC could be identified.

[0057] In this case, as a matter of course, the replica code D_{LC} that could be obtained an affirmative result at the step SP32 becomes the long code LC existing in the received signal S10. Moreover, in the case of identifying the long code LC just after the processing shown in Fig. 8, the processing up to the step SP24 in Fig. 9 can be omitted.

[0058] In this connection, Fig. 7E and 7F show the relation between the correlation detection timing of the group identification short code GISC and the correlation detection timing of the long code LC. More specifically, after the correlation value S30 of the replica code D_{GISC} is detected, the received signal S10 for the time T1 is captured and the correlation value S30 of this received signal S10 with the replica code D_{LC} of the long code LC is calculated, so that the correlation detection timing of the long code LC becomes the time which is approximately the time T1 elapsed after the correlation of the group identification short code GISC was detected.

[0059] According to the foregoing construction, in this first embodiment, firstly, the timing of long code LC is detected by detecting the common short code CSC over the masked segment existing in the received signal S10 in utilizing the replica code D_{CSC} of the common short code CSC. Then, holding the received signal S10 of the time when the common short code CSC was detected in the matched filter 42, and by sequentially detecting the correlation between that received signal S10 and the replica code D_{GISC} of the group identification short code GISC, the group identification short code GISC in the received signal S10 is identified. When the group identification short code GISC can be detected, the received signal S10 following the group identification short code GISC is captured and the received signal S10 is held in the matched filter 42, and by sequentially detecting the correlation between the received signal S10 and the replica code D_{LC} of the long code LC, the long code LC in the received signal S10 is identified.

[0060] In this case, since during the processing from the detection of the common short code CSC to the identification of the group identification short code GISC, the received signal S10 of the time when the common short code CSC is detected is held in the matched filter 42 and the correlation detection is conducted to the received signal S10 and the group identification short code GISC is identified, the time interval between processing does not occur as compared with the conventional method to capture the received signal at the timing of the common short code CSC and identify the group identification short code GISC after detecting the common short code CSC thoroughly once, and thus the time necessary for processing till identifying the group identification short code GISC can be shortened. Also, in that case, by holding this received signal S10, the detection processing is conducted on the same received signal S10, so that this would not be directly affected by the condition change of the transmission path, different from the conventional case.

[0061] Moreover, during the processing from the identification of the group identification short code GISC to the identification of the long code LC, the received signal S10 for the length of time T1 is captured based on the received signal S10 of the time when the group identification short code GISC was identified, and the long code LC will be identified by detecting the partial correlation by the replica code D_{LC} with respect to this received signal S10, so that the processing till identifying the long code LC can be conducted at high speed as compared with the conventional case.

[0062] According to the foregoing construction, since data is held in the matched filter 42 and by switching replica codes DCSC, DGISC and DLC with respect to that data, and the correlation detection is conducted to identify each code, the processing up to the identification of long code LC can be conducted at high speed as compared with the conventional case.

[0063] In Fig. 10, 50 generally shows a short code correlation detecting device for obtaining timing of the long code LC by adding correlation values of short codes of the common short code CSC and the group identification short code GISC.

[0064] In the matched filter 51 the received signal S10 to be correlation-detected is entered, and the matched filter 51 sequentially captures this received signal S10 into the internal shift register based on the data shift clock D_{CLK1} to be supplied from the outside. Then, the matched filter 51 sequentially calculates the correlation values S40 between

this received signal S10 and each of replica codes D_{CSC} and D_{GISC} of the common short code CSC and the group identification short code GISC to be supplied alternatively from the short code generator 52 and outputs these to the latch circuit 54 and the adder 55.

[0065] The latch circuit 54 latches the correlation value S40 on the replica code D_{GISC} of group identification short code GISC to be transmitted from the matched filter 51 based on the data latch clock D_{CLK2} supplied from the controller 53, and outputs this to the adder 55 as the correlation value S41. The adder 55 calculates combined correlation value S42 by adding the correlation value S40 on the replica code D_{CSC} of the common short code CSC and the replica code D_{GISC} of the group identification short code GISC and outputs it as the detection correlation value.

[0066] The short code generator 52 generates replica code D_{CSC} of the common short code CSC and replica code D_{GISC} of group identification short code GISC alternatively based on the control signal S43 to be supplied from the controller 53 and outputs these to the matched filter 51.

[0067] At this point, the correlation detection operation in the short code correlation detecting device 50 will be described in detail referring to timing charts shown in Figs. 11A to 11F. As shown in Figs. 11A and 11B, in this short code correlation detecting device 50, the data shift clock D_{CLK1} which rises at approximately middle timing with respect to the timing of each bit of input received signal S10 is supplied, and bits of the received signal S10 are captured into the internal shift register at the rising edge of the data shift clock D_{CLK1}.

[0068] Moreover, in the short correlation detecting device 50, as shown in Fig. 11C, the data shift clock D_{CLK1} generates replica code D_{CSC} of the common short code CSC over the segment during which the level of the data shift clock D_{CLK1} is "L", and generates replica code D_{GISC} of the group identification short code GISC over the segment during which the level of data shift clock is "H", and thus, replica codes D_{CSC} and D_{GISC} are alternatively generated within one cycle of the data shift clock D_{CLK1}.

[0069] The matched filter 51, by sequentially calculating the correlation values between each of replica codes D_{CSC} and D_{GISC} to be generated at such timing and the received signal S10 entered into the shift register, generate the correlation values S40 on the replica codes D_{CSC} and D_{GISC} alternatively as shown in Fig. 11D.

[0070] As shown in Fig. 11E, the controller 53 generates data latch clock D_{CLK2} of which level becomes "H" at the timing of generating the correlation value S40 on the replica code D_{GISC}. Thus, the latch circuit 54 holds the correlation value S40 on the replica code D_{GISC} by latching the correlation value S40 based on this data latch clock D_{CLK2}, and transmits this as the correlation value S41.

[0071] Then, as shown in Fig. 11F, in the adder 55, by adding this correlation value S41 to the correlation value S40 at the timing of outputting the correlation value S40 on the replica code D_{CSC}, the combined correlation value S42 in which the correlation value on the replica code D_{GISC} and the correlation value on the replica code D_{CSC} are combined can be obtained. And if the timing of long code LC is detected comparing this combined correlation value S42 with the prescribed threshold value as in the case of the first embodiment, the timing of long code LC can be detected considering both the common short code CSC and the group identification short code GISC, and thus, the timing of long code LC can be detected with high precision.

[0072] Note that, the correlation value S40 on the replica code D_{CSC} and the correlation value S41 on the replica code D_{GISC} are combined in the adder 55. However, not only the combined correlation value S42 but also the correlation value ratio between replica codes D_{CSC} and D_{GISC} in the combined correlation value S42 can be calculated and this correlation value ratio can be transmitted. With this arrangement, the timing detection considering each correlation value based on the correlation value ratio can be conducted, and thus, the timing of long code LC can be detected with higher precision. Moreover, when the common short code CSC and group identification short code GISC are already known as in the case of intermittent receiving, signals from a desired station can be identified only by the judgment using the correlation value ratio, and thereby the rising time can be accelerated and power can be saved more efficiently.

[0073] According to the foregoing construction, by switching the plurality of replica codes D_{CSC} and D_{GISC} during the data shift timing of the matched filter 51, almost simultaneously the correlation values of multiple replica codes are calculated and the combined correlation value S42 is calculated, so that the timing detection can be conducted with higher precision if the timing detection of long code LC using this combined correlation value S42 is be conducted.

[0074] In General, since the received signal S10 has been quadrature phase shift keying (QPSK) modulated, the matched filter shown in Figs. 5 and 10 practically has four-phase construction. Here, the matched filter having four-phase construction will be explained referring to Fig. 12.

[0075] In Fig. 12, in which the corresponding parts of Fig. 4 are designated the same reference numerals, 60 generally shows the matched filter having four-phase construction according to the present invention, and in-phase data U_I and quadrature data U_Q obtained by digital converting in-phase element SI and quadrature element SQ separated from the received signal S10 will be entered into correlators 61 and 62 respectively.

[0076] The correlators 61 and 62 are matched filters for detecting the correlation value per each signal element. And data shift clock D_{CLK1} is entered in these correlators 61 and 62, and the correlators 61 and 62 sequentially capture the in-phase data U_I and quadrature data U_Q in their internal shift register based on this data shift clock D_{CLK1} respectively

[0077] The correlation coefficient generator 63 is a circuit to generate replica code for correlation detection based on the control signal S50, in which in-phase element replica code U_{IR} and quadrature element replica code U_{QR} out of the replica code are generated alternatively and outputted to the correlators 61 and 62 respectively as the correlation coefficient.

[0078] The correlator 61 detects the correlation values U_{II} (= U_I * U_{IR}) and U_{IQ} (= U_I * U_{QR}) between respective replica codes U_{IR}, U_{QR} to be supplied alternatively as the correlation coefficient and the in-phase data U_I, and outputs these to the adder 65 and latch circuit 66 as the correlation value S51. The latch circuit 66 latch-holds the correlation value U_{IQ} out of the correlation value S51 based on the data latch clock D_{CLK2} to be supplied from the controller 64 and outputs this to the differentiator 67 as the correlation value S52.

[0079] On the other hand, the correlator 62 alternatively detects the correlation values U_{QI} (= U_Q * U_{IR}) and U_{QQ} (= U_Q * U_{QR}) between respective replica codes U_{IR}, U_{QR} to be supplied alternatively as the correlation coefficient and the quadrature data U_Q, and outputs these as the correlation value S53 to the differentiator 67 and the match circuit 68. The latch circuit 68 latch holds the correlation value U_{QQ} out of correlation value S53 based on the data latch clock D_{CLK2} to be supplied from the controller 64 and transmits this to the adder 65 as the correlation value S54.

[0080] The adder 65 adds up the correlation value U_{II} out of correlation value S51 and the correlation value U_{QQ} supplied as the correlation value S54 and transmits the resultant correlation value V_I (= U_{II} + U_{QQ}) to the squaring circuit 69. The differentiator 67 calculates the difference between the correlation value U_{QI} out of correlation value S53 and the correlation value U_{IQ} to be supplied as the correlation value S52, and outputs the resultant correlation value V_Q (= U_{QI} - U_{IQ}) to the squaring circuit 70.

[0081] Thus obtained correlation values V_I and V_Q are squared respectively with the squaring circuits 69 and 70, and by adding the squared results V_I^2 and V_Q^2 with the adder 71, the correlation value S55 between the received signal S10 and the replica code to be correlation-detected, can be obtained.

[0082] At this point, the correlation detection operation in the four-phase constructed matched filter 60 will be described more specifically using timing charts shown in Figs. 13A to 13I. As shown in Figs. 13A and 13B, in this matched filter 60, the data shift clock D_{CLK1} to rise approximately at the middle timing with respect to the timing of each bit of input in-phase data U_I and quadrature data U_Q is be supplied to correlators 61 and 62. The correlators 61 and 62 sequentially capture the in-phase data U_I and the quadrature data U_Q at the rising edge of the data shift clock D_{CLK1} into the internal shift register respectively.

[0083] Furthermore, as shown in Fig. 13C, the correlation coefficient generator 63 generates the replica code U_{IR} of in-phase element over the segment in which the level of data shift clock D_{CLK1} is "L" and it generates the replica code U_{QR} of quadrature element over the segment in which the level of data shift clock D_{CLK1} is "H". And thus, replica codes U_{IR} and U_{QR} of in-phase element and quadrature element are alternatively generated every one cycle of the data shift clock D_{CLK1}.

[0084] The correlator 61, by sequentially calculating correlation values between respective replica codes U_{IR} and U_{QR} to be generated at such timing and the in-phase data U_I captured into the shift register, generates correlation values U_{II} and U_{IQ} on replica codes UIR and U_{QR} alternatively as shown in Fig. 13D. Similarly, the correlator 62, by sequentially calculating correlation values between respective replica codes U_{IR} and U_{QR} to be generated at such timing and the quadrature data U_Q captured into the shift register, generates correlation values U_{QI} and U_{QQ} on replica codes U_{IR} and U_{QR} alternatively as shown in Fig. 13E.

[0085] As shown in Fig. 13F, the controller 64 generates data latch clock D_{CLK2} of which level becomes "H" at the timing of generating correlation values U_{IQ} and U_{QQ} on the replica code U_{QR}. Thus, the latch circuit 66 holds the correlation value U_{IQ} based on this data latch clock D_{CLK2} and outputs this to the differentiator 67. Similarly, the latch circuit 68 holds the correlation value U_{QQ} based on the data latch clock D_{CLK2} and outputs this to the adder 65.

[0086] As shown in Fig. 13G, the adder 65 calculates the correlation value V_I (= U_{II} + U_{QQ}) by adding the correlation value U_{QQ} to the correlation value U_{II} at the timing of transmitting the correlation value U_{II} from the correlator 61. Similarly, the differentiator 67 calculates the correlation value V_Q (= U_{QI} - U_{IQ}) by subtracting the correlation value U_{IQ} from the correlation value U_{QI} at the timing of transmitting the correlation value U_{QI} from the correlator 62.

[0087] With the above arrangement, after doubling correlation values VI and V_Q at the square-law circuits 69 and 70 respectively, by adding these doubled results V_{I2} and V_{Q2}, the correlation value S55 corresponding to the replica code to be correlation-detected can be obtained.

[0088] Accordingly, in the case of this matched filter 60, correlation coefficients U_{IR} and U_{QR} are alternatively generated between the data shift timing of in-phase data U_I and quadrature data U_Q, and using these correlation coefficients U_{IR} and U_{QQ} the correlation values U_{II}, U_{IQ} and U_{QI}, U_{QQ} are alternatively generated at the correlators 61 and 62. Therefore, four correlation values U_{II}, U_{IQ}, U_{QI} and U_{QQ} can be generated without providing separate four correlators as the conventional device, and thereby the circuit configuration of the four-phase matched filter can be simplified as compared with the conventional device.

[0089] Next, a synchronization detection device according to second embodiment of this invention will be described.

[0090] In Fig. 14, 80 generally shows a synchronization detection device according to this embodiment, and long

code LC included in the received signal S10 is identified at high speed by controlling each circuit with a controller 81.

[0091] Also in the case of this embodiment, the received signal S10 is entered into the matched filter 82, and the matched filter 82 sequentially enters that received signal S10 into the internal shift register based on the data shift clock D_{CLK1} supplied from the controller 81. Then, the matched filter 82 sequentially calculates the correlation value S60 between each bit of the received signal S10 captured and the replica code D_R to be correlation-detected that is generated in the correlation coefficient generator 83, and transmits these to the controller 81, latch circuit 84 and adder 85.

[0092] The correlation coefficient generator 83 generates replica code D_{CSC} of the common short code CSC, replica code D_{GISC} of the group identification short code GISC or the replica code in which the replica code D_{CSC} of common short code CSC is multiplied by the replica code D_{LC} of long code LC, based on the control signal S61 from the controller 81, and transmits this to the matched filter 82 as the replica code D_R to be correlation-detected.

[0093] The latch circuit 84 latch-holds the desired correlation value out of the correlation values S60 to be transmitted from the matched filter 82 based on the data latch clock D_{CLK2} supplied from the controller 81 and outputs this to the AND circuit 86 and the controller 81 as a correlation value S62. The control signal S63 from the controller 81 is entered into the other input terminal of the AND circuit 86, and when the level of the control signal S63 is "H", the AND circuit 86 outputs the correlation value S62 to the adder 85.

[0094] The adder 85 adds up the correlation value S60 to be sent out from the matched filter 82 and the correlation value S62 to be transmitted via the AND circuit 86, and outputs the resultant correlation value S64 to the comparator 87 and the controller 81. Note that, if the correlation value S62 is outputted from the AND circuit 86, the adder 85 outputs the correlation value S60 as it is as the correlation value S64.

[0095] The comparator 87 receives threshold data D_{TH} from the controller 81 and compares the threshold value which this threshold data D_{TH} shows with the included correlation value S64, and if the value of the correlation value S64 exceeds the threshold value, the comparator 87 outputs detection data S_{DET} to the controller 81.

[0096] The first timer 88, receiving a count start command S65 from the controller 81, counts up to the time of the mask cycle T_{MK} of long code LC shown in Fig. 7, and when the counting is ended, outputs count end information S66 to the controller 81. Moreover, when the second timer 89, receiving the count command S67 from the controller 81, counts up to the time to capture the received signal S10 for detecting the partial correlation (more precisely, the time T1 corresponding of one cycle of the common short code CSC shown in Fig. 7), and when the counting is ended, it outputs count end information S68 to the controller 81.

[0097] Here, the correlation coefficient generator 83 provided in the synchronization detection device 80 described above will be explained more specifically with reference to Fig. 15. As shown in Fig. 15, the correlation coefficient generator 83 is roughly comprised of two pseudo noise code (PN) decoders 90 and 91, and replica code D_R is generated by operating these two PN decoders 90 and 91 based on the control signal S61 (i.e., $D_{SC\text{-}INT}$, $D_{LC\text{-}INT}$, D_{CLK3} and S_{MSK}).

[0098] The first PN decoder 90 is a decoder to generate replica code D_{CSC} of the common short code CSC or replica code D_{GISC} of the group identification short code GISC, and when it receives the initial value $D_{SC\text{-}INT}$ of the common short code CSC or group identification short code GISC, generates data code for one cycle of the corresponding short code CSC or GISC at once and outputs this as the replica code D_{CSC} or D_{GISC}.

[0099] On the other hand, the second PN decoder 91 is a decoder to generate replica code D_{LC} of the long code LC for detecting the partial correlation, and generates partial long code corresponding to the length for just one cycle of short code out of long code LC, based on the first initial value $D_{LC\text{-}INT}$ of the long code LC to be supplied from the controller 81 via the switch 93 or the second initial value $D_{LC\text{-}INT}'$ of the long code LC to be supplied from the latch circuit 95 via the switch 93, and outputs this as replica code D_{LC} of the long code LC.

[0100] When the data decoder 94 receives the initial value $D_{LC\text{-}INT}$ of the long code LC via the switch 93, it forms the initial value D1 for generating the partial long code corresponding to the length for one cycle of the following short code and outputs this to the latch circuit 94. The latch circuit 94 holds this initial value D1 based on the data latch clock D_{CLK3} supplied from the controller 81 and outputs this as the second initial value $D_{LC\text{-}INT}$.

[0101] Note that, upon receiving the second initial value $D_{LC\text{-}INT}$ via the switch 93, the decoder 94 forms and transmits the initial value D1 for generating partial long code corresponding to the length for one cycle of the following short code. And by sequentially repeating this processing, the data decoder 94 forms the initial value D1 to generate the partial long code having a desired phase.

[0102] The replica code D_{LC} of the long code LC generated in the second PN decoder 91 is entered into AND circuit 96. At the other input terminal of this AND circuit 96 the mask control signal S_{MSK} to be transmitted from the controller 81 is entered and the AND circuit 96 sends out the replica code D_{LC} only when the level of the mask control signal S_{MSK} is "H".

[0103] An exclusive OR circuit 97 conducts the exclusive OR calculation of the replica code D_{CSC} or D_{GISC} transmitted from the first PN decoder 90 and the replica code D_{LC} transmitted via the AND circuit 96, and outputs the resultant code to the matched filter 82 as the replica code D_R. Note that, since this is the exclusive OR calculation, if the replica

code D_{LC} is not transmitted from the AND circuit 96, the replica code D_{CSC} or D_{GISC} is transmitted as it is.

[0104] Here, the principle of replica code generation of PN decoders 90 and 91 described above will be explained. However, in order to simplify the explanation, let the code to be generated at the PN decoder to be PN95. In Fig. 16, 100 is a general PN decoder to generate the PN95 code, and this comprises a shift register 101 having nine stages and an exclusive OR circuit 102. In this PN decoder 100, output of the register D4 and output of the register D0 are entered into the exclusive OR circuit 102, and by entering the result of the exclusive OR calculation into the register D8, PN code is sequentially transmitted.

[0105] Supposing I8 ~ I0 to be the initial values of D8 ~ D0, the output O0 at T=0 becomes I0, and when T=1, the value of the shift register 101 shifts to the right by one and the output O1 becomes I1. Moreover, at that time the result of exclusive OR calculation of I4 and I0 is entered into the register D8.

[0106] Similarly, when T=2, the output O2 becomes I2, and the results of exclusive OR calculation of I1 and I5 are entered into the register D8. Repeating this operation, the output code to be transmitted from the PN decoder 100 become initial values I0 to I8, or the result of exclusive OR operation of the output value of the predetermined time. Taking this into consideration, the output codes O0 to O19 at the time T = 0 to 19 can be expressed by the exclusive OR operation based on the initial values I0 to I8. Accordingly, the PN decoder 103 which outputs the output codes O0 ~ O19 at once at the same time can be constructed by the gate circuit using exclusive OR circuits EX1 to EX11 as shown in Fig. 17. Buffers B1 to B9 provided in the PN decoder 103 are devices to generate delay time for absorbing the operation time in the exclusive OR circuits EX1 to EX11.

[0107] The first and the second PN decoders 90 and 91 are formed by the gate circuit using the exclusive OR circuit based on the principle described above. When the initial value $D_{SC\text{-}INT}$ is given to the first PN decoder 90, this first PN decoder 90 generates replica code D_{CSC} of the common short code CSC or the replic code D_{GISC} of the group identification short code GISC for one cycle at once, and when the initial value $D_{LC\text{-}INT}$ or $D_{LC\text{-}INT'}$ is given to the second PN decoder 91, this second PN decoder 91 forms replica code D_{LC} of the partial long code corresponding to the length for one cycle of the short code at once.

[0108] Since the PN decoders 90 and 91 to generate replica code D_{CSC}, D_{GISC} or D_{LC} of the fixed length are provided in this synchronization detection device 80, the correlation detection can be conducted at high speed giving the correlation coefficients to the matched filter 82 all at once. However, the general PN decoder 100 which generates codes in time series is used causes the problem that it takes time to generate the replica code of the fixed length and accordingly to detect the correlation .

[0109] The replica code D_{LC} is the partial code of the long code LC. In order to detect the correlation with the long code LC, it is desirous to generate the partial code having a desired phase of the long code LC. However, considering the principle of code generation of the PN decoder, output code is determined by the value in the shift register. Thus, if the value in the shift register at the fixed time is calculated and this would be entered into the second PN decoder 91, the partial code of the desired phase can be easily generated without changing the circuit construction. The task of the data decoder 95 described above is to calculate the value in the shift register at the fixed time.

[0110] Here, the principle of data calculation in the data decoder 5 will be explained. In general, the value in the shift register at the predetermined time T = X can be obtained by the exclusive OR calculation of the initial value of the shift register and the matrix corresponding to the amount of shift of the shift register. For example, if the code to be generated is taken to be PN 95, the value I8' ~ I0' in the shift register at T = 9 can be expressed as following equation (1):

$$\begin{bmatrix} 10' \\ 11' \\ 12' \\ 13' \\ 14' \\ 15' \\ 16' \\ 17' \\ 18' \end{bmatrix} = \begin{bmatrix} 10 \oplus 14 \\ 11 \oplus 15 \\ 12 \oplus 16 \\ 13 \oplus 17 \\ 14 \oplus 18 \\ 10 \oplus 14 \oplus 15 \\ 11 \oplus 15 \oplus 16 \\ 12 \oplus 16 \oplus 17 \\ 13 \oplus 17 \oplus 18 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \end{bmatrix} \oplus \begin{bmatrix} 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \end{bmatrix} \quad \cdots\cdots(1)$$

[0111] If this transform matrix is taken as A shown by the following equation (2), this is a matrix for obtaining the value in the shift register when the time "9" has passed from the reference time:

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \end{bmatrix} \quad \ldots\ldots(2)$$

[0112] Accordingly, in the case of obtaining values I8" ~ I0" in the shift register at the time T = 18, as shown in the following equation (3), these values can be obtained by the calculation using the transform matrix A making values I8' ~ I0' in the shift register as the initial value at T = 9.

$$\begin{bmatrix} 10'' \\ 11'' \\ 12'' \\ 13'' \\ 14'' \\ 15'' \\ 16'' \\ 17'' \\ 18'' \end{bmatrix} = \begin{bmatrix} 10 \oplus 18 \\ 10 \oplus 11 \oplus 14 \\ 11 \oplus 12 \oplus 15 \\ 12 \oplus 13 \oplus 16 \\ 13 \oplus 14 \oplus 17 \\ 14 \oplus 15 \oplus 18 \\ 10 \oplus 14 \oplus 15 \oplus 16 \\ 11 \oplus 15 \oplus 16 \oplus 17 \\ 12 \oplus 16 \oplus 17 \oplus 18 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \end{bmatrix} \oplus \begin{bmatrix} 10 \oplus 14 \\ 11 \oplus 15 \\ 12 \oplus 16 \\ 13 \oplus 17 \\ 14 \oplus 18 \\ 10 \oplus 14 \oplus 15 \\ 11 \oplus 15 \oplus 16 \\ 12 \oplus 16 \oplus 17 \\ 13 \oplus 17 \oplus 18 \end{bmatrix} = A \oplus \begin{bmatrix} 10' \\ 11' \\ 12' \\ 13' \\ 14' \\ 15' \\ 16' \\ 17' \\ 18' \end{bmatrix}$$

.....(3)

[0113] Accordingly, as the data decoder it may just conduct the exclusive OR calculation corresponding to this transform matrix. And as shown in Fig. 18, the data decoder 105 to obtain the value in the shift register when the time "9" has passed, can be constructed only by the exclusive OR circuits EX20 to EX26.

[0114] The data decoder 95 described above is formed only by the exclusive OR circuit based the above principle, and by conducting the exclusive OR calculation making the initial value $D_{LC\text{-}INT}$ or $D_{LC\text{-}INT}'$ of the fixed time as an input, it generates the initial value $D_{LC\text{-}INT}'$ for generating the partial code of long code LC of the following phase. In this synchronization detection device 80, by providing such data decoder 95, the partial code of the desired phase can be easily generated without changing the circuit construction of the PN decoder 91 by calculating the initial value $D_{LC\text{-}INT}'$ having a desired phase by the data decoder 95.

[0115] The operational procedure in the synchronization detection device 80 will be explained referring to Figs. 19 and 20. Fig. 19 shows the processing from the timing detection of long code LC by the common short code CSC to the identification of group identification short code GISC, and Fig. 20 shows the processing from the group identification by the group identification short code GISC to the identification of the long code LC.

[0116] As shown in Fig. 19, in the case of identifying the group of long code LC, at the step SP41 following the start step SP40, the controller 81, supplying the initial value $D_{SC\text{-}INT}$ of the common short code CSC as the control signal S61 to the first PN decoder 90 in the correlation coefficient generator 83, makes the correlation coefficient generator 83 generate replica code D_{CSC} of the common short code CSC.

[0117] Then, at the following step SP42, the controller 81, giving the first threshold value V_{TH1} for detecting the common short code CSC to the comparator 87 as the threshold data D_{TH}, sets the first threshold value V_{TH1} to the

comparator 87. Then, at the next step SP43, supplying data shift clock D_{CLK1} to the matched filter 82, the controller 81 releases the hold state of the matched filter 82 and makes this capture the received signal S10 successively. Thus, the matched filter 82 starts the correlation value calculation between the received signal S10 and the replica code D_{CSC}.

[0118] At the following step SP44, the controller 81 judge whether the correlation value S60 to be transmitted from the matched filter 82 exceeds the first threshold value V_{TH1} or not. More specifically, the comparator 89 compares the correlation value S64 supplied via the adder 85 with the first threshold value V_{TH1}, and when the correlation value S64 exceeds the first threshold value V_{TH1}, the detection data S_{DET} is sent out. Therefore, the controller 81 conducts this judgment based on whether this detection data S_{DET} is obtained or not.

[0119] As a result of this judgment in this step SP44, when the correlation value S60 supplied from the matched filter 82 exceeds the first threshold value V_{TH1}, the controller 81 moves to the following step SP4 assuming that the common short code CSC has been detected. At the step SP45, the controller 81 captures the correlation value S60 of the time when it exceeds the first threshold value V_{TH1} and sets the value of this correlation value S60 to the comparator 87 as the second threshold value V_{TH2}.

[0120] At the following step SP46, the controller 81 makes the first timer 88 count up to the mask cycle T_{MK} of the long code LC by transmitting a count start command S65 to the first timer 88. At the next step SP47, the controller 81, judging whether the count stop information S66 has been obtained or not from th first timer 88, judges whether the mask cycle T_{MK} has passed or not. As a result, if the mask cycle has not passed, the controller 81 moves to the step SP48, and if the mask cycle time has passed, it proceeds to the step SP49.

[0121] At the step SP48, the controller 81 judges whether the correlation value S60 supplied from the matched filter 82 exceeds the second threshold value V_{TH2} or not. As a result, if the correlation value S60 exceeds the second threshold value V_{TH2}, the controller 81 returns to the step SP45 and resets the then correlation value S60 as the second threshold value V_{TH2} and repeats the same processing. On the other hand, if the correlation value S60 has not exceeded the second threshold value V_{TH2}, the controller 81 returns to the step SP47 and repeats this processing until the timer stops. More specifically, in the processing from the step SP45 to the step SP48, it is detected whether the correlation value detected first is the largest correlation value or not in the mask cycle T_{MK}, and if this is the largest correlation value, it proceeds to the step SP49, and if another large correlation value exists, it is detected whether it is the largest correlation value in the mask cycle T_{MK} or not.

[0122] With the above arrangement, when the largest correlation value in the mask cycle T_{MK} is detected, the controller 81 moves to the step SP49 assuming that the common short code CSC can be detected. At the step SP49, the controller 81, stopping the supply of data shift clock D_{CLK1} to the matched filter 82, stops the bit shift operation of the shift register in the matched filter 82. And thus, it holds the received signal S10 of the time when the common short code CSC is detected in the shift register.

[0123] At the following step SP50, the controller 81, multiplying the second threshold value V_{TH2} set finally to the comparator 87 by the predetermined numbers, sets this to the comparator 87 newly as the third threshold value V_{TH3} for detecting group identification short code GISC. At the following step SP51, the controller 81, supplying the initial value $D_{SC\text{-}INT}$ for generating replica code D_{GISC} of the first candidate group identification short code GISC to the first PN decoder 90 of the correlation coefficient generator 83, causes the correlation coefficient generator 83 to generate the replica code D_{GISC} of the first candidate group identification short code GISC. Thus, the matched filter 82 starts the calculation of correlation values between the received signal S10 being held in the shift register and the replica code D_{GISC}.

[0124] At the following step SP52, the controller 81 judges whether the correlation value S60 output from the matched filter 82 exceeds the third threshold value V_{TH3} or not, based on the detection data S_{DET} from the comparator 87. As a result, if the correlation value S60 has not exceeded the third threshold value V_{TH3}, the controller 81 proceeds to the step SP53 and causes the correlation coefficient generator 83 to generate the next candidate replica code D_{GISC} of the group identification short code GISC and returning to the step SP52 again, it conducts the judgment on the correlation value S60.

[0125] Accordingly, as a result of successively generating the candidates of the group identification short code GISC and determining the correlation value S60, if the correlation value S60 exceeds the third threshold value V_{TH3}, the controller 81 moves to the step SP54 and terminates the processing assuming that the group identification short code GISC can be identified. In this case, as a matter of course, the replica code D_{GISC} obtained the affirmative result at the step SP52 becomes the group identification short code GISC existing in the received signal S10. Also, if the group identification short code GISC could be identified, the position at which the group identification short code GISC is inserted in the long code LC is known, and this means that the timing of long code LC can be detected. Moreover, because the group identification short code GISC could be identified, this means that the group of long code LC existing in the received signal S10 can be specified to the group shown by the group identification short code GISC.

[0126] Here, an example of the timing chart up to the group identification when the processing of Fig. 19 is conducted will be shown in Figs. 21A to 21C. Firstly, at the time t1, as well as generating the replica code D_{CSC} of the common short code CSC, data shift clock D_{CLK1} is supplied to the matched filter 82, the matched filter 82 sequentially captures

received signal S10 and calculates the correlation value S60 with the replica code D_{CSC}. As a result, at time t2, if the correlation value S60 from the matched filter 82 exceeds the first threshold value V_{TH1}, it sets the correlation value S60 of that time as the second threshold value V_{TH2}, and simultaneously starts the first timer 88 and compares the correlation value S60 supplied again from the matched filter 82 with the second threshold value V_{TH2}.

[0127] As a result, as shown in Figs. 21A to 21C, if the correlation value S60 exceeds the second threshold value V_{TH2} at the time t3 before the first timer 88 stops, the then correlation value S60 is set again as the second threshold value V_{TH2}, and the first timer 88 starts. As a result, if there is no correlation value S60 that exceeds the second threshold value V_{TH2} before the first timer 88 stops, the supply of the data shift clock D_{CLK} is stopped at the time point t4 to cause the matched filter 82 to hold the received signal S10 therein and moreover, the value of the correlation value S60 detected at the time point t3 which is multiplied by the predetermined numbers is reset as the third threshold value V_{TH3}. Furthermore, the replica code D_{GISC}, which is the first candidate of the group identification short code GISC, is generated from the correlation coefficient generator 83.

[0128] Under such conditions the value of the correlation value S60 transmitted from the matched filter 82 is compared with the third threshold value V_{TH3}, and if the correlation value S60 does not exceed the third threshold value V_{TH3}, the next candidate replica code D_{GISC} is generated and also the correlation value S60 is be determined. As a result, at the time point t5 if the correlation value S60 exceeds the third threshold value V_{TH3}, the then replica code D_{GISC} is determined as the group identification short code GISC in the received signal S10 and the processing is terminated. Thus, in this synchronization detection device 80, the group identification short code GISC is identified according to the processing described above.

[0129] Next, the processing up to the long code LC identification will be explained referring to Fig. 20. In Fig. 20, assuming that the group identification short code GISC could be detected in the past according to the processing shown in Fig. 19, the long code LC is identified using that group identification short code GISC at the time of intermittently reception. As shown in this Fig. 20, at the step SP61 following the start step SP60, the controller 81, firstly by giving the initial value $D_{SC\text{-}INT}$ to generate the replica code D_{CSC} of the common short code CSC and the initial value $D_{SC\text{-}INT}$ to generate the replica code D_{GISC} of the group identification short code GISC to the first PN decoder 90 of the correlation coefficient generator 83 alternatively, causes the correlation coefficient generator 83 to generate the replica code D_{CSC} and the replica code D_{GISC} alternatively.

[0130] Then at the following step SP62, the controller 81 sets the fourth threshold value V_{TH4} for detecting both common short code CSC and group identification short code GISC to the comparator 87. At the following step SP63, the controller 81, giving the data shift clock D_{CLK1} to the matched filter 82, releases the hold state of the matched filter 82 and makes the matched filter 82 start the correlation calculation operation. Thus, the matched filter 82, receiving the replica codes D_{CSC} and D_{GISC} to be supplied alternatively within one cycle of the data shift clock D_{CLK1}, calculates the correlation value between respective replica codes D_{CSC}, D_{GISC} and the received signal S10, outputs this as the correlation value S60. At this point, the controller 81, as well as giving the data latch clock D_{CLK2} to the latch circuit 84, gives the control signal S63 having the level "H" to the AND circuit 86, and causes the latch circuit 84 to latch the correlation value S60 of the replica code D_{GISC} and supplies that value to the adder 85. Thus, the adder 85 obtains the correlation value S64 in which the correlation value of the replica code D_{CSC} and the correlation value of the replica code D_{GISC} are added.

[0131] At the following step SP64, the controller 81 judges whether the correlation value S64 transmitted from the adder 85 exceeds the fourth threshold value V_{TH4} or not.

[0132] As a result of this judgment, if the correlation value S64 exceeds the fourth threshold value V_{TH4}, the controller 81 moves to the following step SP65 assuming that the common short code CSC and the group identification short code GISC could be detected. At the step SP65, the controller 81, sending the count start command S67 to the second timer 89, causes the second timer 89 to count up to the time T1 to capture the received signal S10 to detect the partial correlation.

[0133] At the following step SP66, the controller 81 judges whether the time T1 has passed or not, based on the count stop information S68 from the timer 89. And if it is found that the time has passed the controller 81 proceeds to the step SP67. At the step SP67, the controller 81, stopping the data shift clock D_{CLK1} to supply to the matched filter 82, stops the bit shift operation of the shift register in the matched filter 82, and makes this hold the received signal S10 currently existing in the shift register.

[0134] At the following step SP68, the controller 81 sets the fifth threshold value V_{TH5} for detecting long code LC to the comparator 87. At the next step SP69, by supplying the initial value $D_{SC\text{-}INT}$ for generating replica code D_{CSC} of the common short code CSC to the first PN decoder 90 of the correlation coefficient generator 83, the controller 81 causes the first PN decoder 90 to generate the replica code D_{CSC}. At the next step SP70, by supplying the initial value $D_{LC\text{-}INT}$ for generating partial code of the first candidate long code LC to the second PN decoder 91 of the correlation coefficient generator 83, the controller 81 makes the second PN decoder 91 generate the first candidate replica code D_{LC}. At the following step SP71, the controller 81, setting the mask control signal S_{MSK} to the level "H", causes the correlation coefficient generator 83 to generate replica code D_R in which the replica code D_{CSC} is multiplied by the

replica code D_{LC}. Then, the matched filter 82 calculates the correlation value S60 between the held received signal S10 and the replica code D_R formed of replica codes D_{CSC} and D_{LC}.

[0135] Then, at the following step SP72, the controller 81 judges whether the correlation value S60 transmitted from the matched filter 82 exceeds the fifth threshold value V_{TH5} or not, based on the detection data S_{DET} transmitted from the comparator 87. As a result, if it is found that the correlation value S60 has not exceeded the fifth threshold value V_{TH5}, the controller 81 proceeds to the step SP73. At this step SP73, the controller 81, by supplying the initial value D_{LC-INT} for generating the next candidate replica code DLC into the second PN decoder 91, makes the second PN decoder 91 generate the next candidate replica code D_{LC} and upon returning to the step SP72, conducts the judgment on the correlation value S60. To be more precise, before moving to the next candidate, replica codes D_{LC} with shifted phase are sequentially generated on that candidate and the correlation is detected. As a result, if there is no correlation value exceeding the threshold value in that candidate, the controller 81 moves to the next candidate. With this arrangement, in this synchronization detection device 80, the phase of long code LC is identified with the identification of long code LC.

[0136] Thus, as a result of judgement of correlation value S60 by sequentially generating candidates of the long code LC, if the correlation value S60 exceeds the fifth threshold value V_{TH5}, the controller 81 moves to the step SP74 assuming that the long code LC has been identified, and terminates the processing.

[0137] In this case, as a matter of course, the replica code D_{LC} obtained an affirmative result in the step SP72 becomes the long code LC existing in the received signal S10. Moreover, in the case of identifying the long code LC continuing immediately after the processing shown in Fig. 19 has been conducted, the processing up to the step SP64 in the process shown in Fig. 20 can be omitted.

[0138] According to the foregoing construction, at first, this synchronization detection device 80 generates replica code D_{CSC} of the common short code CSC for detecting common short code CSC to regulate timing of long code LC, and calculates the correlation value S60 between the received signal S10 and the replica code D_{CSC} by sequentially capturing the received signal S10 with the matched filter 82. Then, this synchronization detection device 80, judging whether the correlation value S60 exceeds the first threshold value V_{TH1} or not, detects the common short code CSC.

[0139] When the common short code CSC can be detected, this synchronization detection device 80 generates the replica code D_{GISC} of the group identification short code GISC and causes the matched filter 82 to hold the received signal S10 of the time when the common short code CSC is detected and to calculate the correlation value S60 between that received signal S10 and the replica code D_{GISC}. Then, successively changing replica code D_{GISC} of the group identification short code GISC, the synchronization detection device 80 identifies group identification short code GISC by judging whether that correlation value S60 has exceeded the second threshold value V_{TH2} or not.

[0140] After detecting the group identification short code GISC, the received signal S10 for calculating partial correlation of the long code LC is captured into the matched filter 82, and when this processing ends, the matched filter 82 is set to be in a hold state, partial replica code D_{LC} of the long code LC is generated, and the correlation value S60 between the received signal S10 and the replica code D_{LC} is calculated with the matched filter 82. And replica codes D_{LC} of the long code LC are sequentially changed in the group specified by the group identification short code GISC, and by judging whether the correlation value S60 exceeds the fifth threshold value V_{TH1} or not, long code LC can be identified.

[0141] Thus, in this synchronization detection device 80, by successively changing the replica codes DR (D_{CSC}, D_{GISC} and D_{LC}) while holding the received signal S10 in the matched filter 82, the correlation value with respect to each replica code can be obtained at high speed and each code can be identified at high speed. And thus, the long code LC included in the received signal S10 can be identified at higher speed as compared with the conventional device.

[0142] According to the foregoing construction, the received signal S10 can be held in the matched filter 82 and by changing the replica codes D_{CSC}, D_{GISC} and D_{LC} at fixed timing, the correlation value S60 can be calculated and each code is to be identified, so that the long code LC included in the received signal S10 can be identified at high speed.

[0143] Note that, in the aforementioned embodiment, the present invention is applied to the cellular radio communication system of asynchronous communication between base stations in DS-CDMA scheme. However, the present invention is not limited thereto and the same effect as aforementioned case can be obtained if the present invention is applied to other systems.

[0144] According to the present invention as described above, a data shift clock to be given to matched filtering means stops at desired timing to hold a received signal, and by changing a replica code generated by the correlation coefficient generating means to a first, second, or third replica code at desired timing and calculating the correlation value of that time, the second code, the third code and the first code are successively detected and the timing and the code group of the first code are detected. Thereby, the matched filtering means can conduct the correlation detection holding the received signal and thus, each correlation detection can be conducted at almost the same timing and the first code included in the received signal can be identified at high speed as compared with the conventional device.

[0145] While there has been described in connection with the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be aimed, therefore, to cover in the

appended claims all such changes and modifications as fall within the true spirit and scope of the invention.

Claims

1. A synchronization detection device for receiving a signal including first code, known second code for detecting timing of said first code and third code for specifying the group of said first code, and for detecting the timing and code type of said first code included in said received signal, comprising:

   a correlation detecting device for sequentially capturing said received signal based on data shift clock supplied, and for receiving replica code corresponding said first, second or third code and detecting a correlation value between said first, second or third replica code and said received signal;
   a correlation coefficient generating device for generating said first, second or third replica code and supplying it to said correlation detecting device; and
   a control device for stopping the supply of said data shift clock at desired timing and causing the correlation detecting device to hold said received signal, and simultaneously, switching the replica code to be generated by said correlation coefficient generating device to said first, second or third replica code at desired timing and detecting said correlation value of that time, and thereby, detecting said second code, said third code and said first code in order to detect the timing and code type of said first code.

2. The synchronization detection device according to claim 1, further comprising

   a comparator for detecting whether said correlation value exceeds a prescribed threshold value or not, wherein said control device detects said correlation value by setting said threshold value of said comparator to a prescribed value in accordance with switching of said replica codes.

3. The synchronization detection device according to claim 2, wherein said control device is for

   firstly, causing said correlation coefficient generating device to generate said second replica code and supplying said data shift clock to said correlation detecting device, in order to cause said correlation detecting device to detect the correlation value on said second replica code, and by judging whether said correlation value exceeds the first threshold value or not, detecting said second code to detect the timing of said first code;
   when said second code is detected, stopping the supply of said data shift clock to cause said correlation detecting device to hold said received signal and making said correlation coefficient generating device generate successively said third replica code which can be considered as a candidate, and by judging whether said correlation value sent from said correlation detecting device at that time exceeds the second threshold value or not, detecting the type of said third code; and
   when said third code is detected, supplying said data shift clock for a fixed period of time to cause said correlation detecting device to capture and hold a fixed length of said received signal, making said correlation coefficient generating device generate said first replica code of the group specified by said third code successively, and by judging whether said correlation value to be transmitted from said correlation detecting device at that time exceeds the third threshold value or not, detecting the type of said first code.

4. The synchronization detection device according to claim 3, wherein
   said first replica code is partial code corresponding to said first code, and in the case of detecting the type of said first code, partial correlation is detected by said correlation detecting device.

5. The synchronization detection device according to claim 2, 3 or 4 wherein:

   said comparator compares a synchronization correlation value generated by adding the correlation value on said second replica code to the correlation value on said third replica code with the threshold value supplied from said control device; and
   said control device detects the timing of said first code by the comparison output from said comparator.

6. The synchronization detection device according to claim 5, wherein
   said control device detects the timing of said first code based on the correlation value ratio of said second replica code and said third replica code of said synchronization correlation value, which is generated by adding said correlation value on said second replica code and said correlation value on said third replica code.

7. The synchronization detection device according to claim 1, wherein said control device is for

firstly generating said second replica code with said correlation coefficient generating device and supplying said data shift clock for a first predetermined period of time to said correlation detecting device, to cause said correlation detecting device to detect the correlation value on said second replica code, and setting a value corresponding to the maximum correlation value within said first predetermined period of time as a first threshold value;
making said correlation coefficient generating device generate said third replica code which can be considered as a candidate in success, and by judging whether said correlation value outputted from said correlation detecting device at that time exceeds said first threshold value or not, detecting the type of said third code;
judging whether the synchronization correlation value, which is generated by adding the correlation value on said second replica code and the correlation value on said detected third replica code, exceeds the second threshold value or not, to detect the timing of said first code; and
supplying said data shift clock for a second predetermined period of time to cause said correlation detecting device to capture and hold a predetermined length of said received signal, making said correlation coefficient generating device generate said first replica code of the group specified by said third code in success, and detecting whether said correlation value outputted from said correlation detecting device at that time exceeds the third threshold value or not, to detect the type of said first code.

8. The synchronization detection device according to any preceding claim, wherein
said correlation detecting device is a matched filter.

9. A synchronization detecting method for receiving a signal including first code, known second code for detecting timing of said first code, and third code for specifying the group of said first code, and detecting the timing and the code type of said first code included said received signal, wherein
supply of data shift clock is stopped at desired timing to hold said received signal, and said second code, said third code, and said first code are detected in order based on the then said correlation value by switching said first, second and third replica codes at desired timing, to detect the timing and code type of said first code.

10. The synchronization detecting method according to claim 9, comprising the steps of:

firstly generating said second replica code and supplying said data shift clock to detect the correlation value of said received signal on said second replica code, and judging whether said correlation value exceeds the first threshold value or not to detect said second code, and detecting the timing of said first code;
next stopping the supply of said data shift clock to hold said received signal, generating said third replica code which can be considered as a candidate in success, and by judging whether the correlation value between said third replica code and said received signal being held at that time exceeds the second threshold value or not, detecting the type of said third code; and
after that, supplying said data shift clock for a predetermined period of time to capture and hold a predetermined length of said received signal, generating said first replica code of the group specified by said third code in success, and by judging whether the then correlation value exceeds the third threshold value or not, detecting the type of said first code.

11. The synchronization detecting method according to claim 9 or 10, wherein
said first replica code is partial code corresponding to said first code, and the type of said first code is detected by detecting partial correlation.

12. The synchronization detecting method according to claim 9, 10 or 11, wherein
a synchronization correlation value is generated by adding said correlation value on said second replica code to said correlation value on said third replica code, to detect the timing of said first code using said synchronization correlation value.

13. The synchronization detecting method according to claim 12, wherein
the timing of said first code is detected based on a correlation value ratio of said second replica code and said third replica code of said synchronization correlation value.

14. The synchronization detecting method according to claim 9, comprising the steps of:

generating said second replica code and supplying said data shift clock for a first predetermined period of time to detect the correlation value between said second replica code and said received signal, and setting a value corresponding to the maximum correlation value within said first predetermined period of time;

generating said third replica code which can be considered as a candidate in success and judging whether the then correlation value exceeds said first threshold value or not, to detect the type of said third code;

judging whether the synchronization value, which is generated by adding the correlation value on said second replica code to the correlation value on said detected third replica code, exceeds the second threshold value, to detect the timing of said first code; and

supplying said data shift clock for a second predetermined period of time to capture and hold a predetermined length of said received signal, successively generating said first replica code of the group specified by said third code, and by judging whether the then correlation value exceeds the third threshold value or not, detecting the type of said first code.

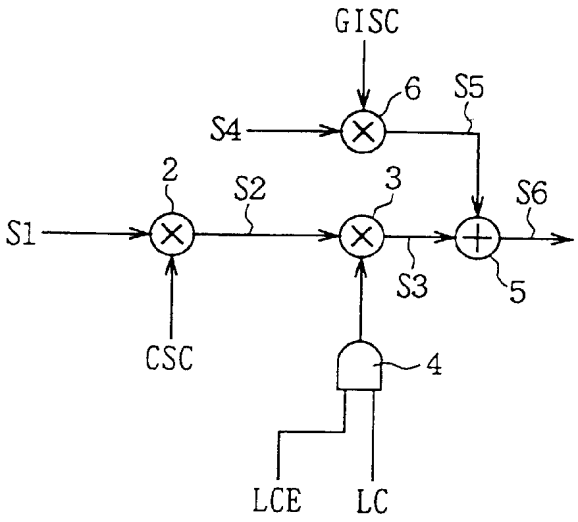


FIG. 1 (RELATED ART)

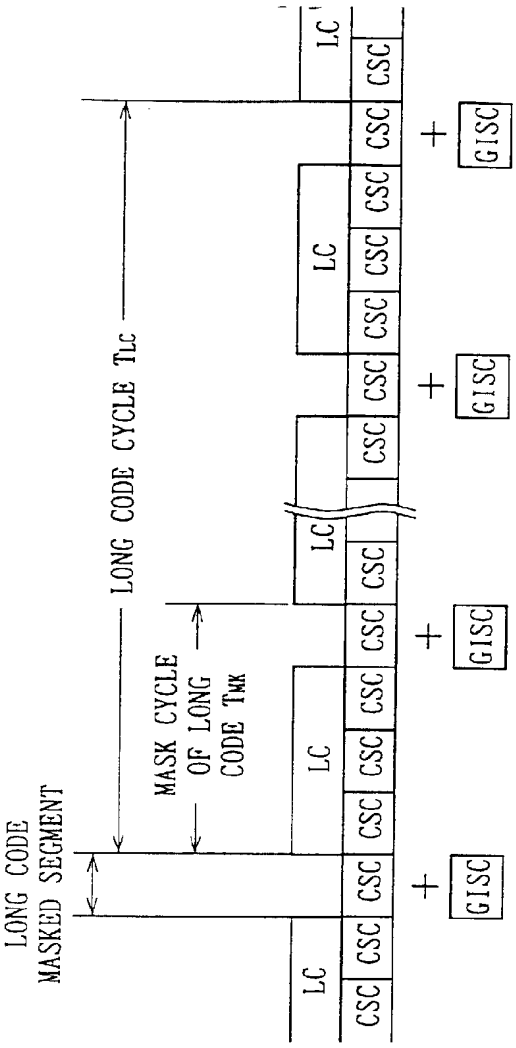


FIG. 2 A (RELATED ART)

LONG CODE

FIG. 2 B (RELATED ART)

COMMON SHORT CODE

FIG. 2 C (RELATED ART)

GROUP IDENTIFICATION SHORT CODE

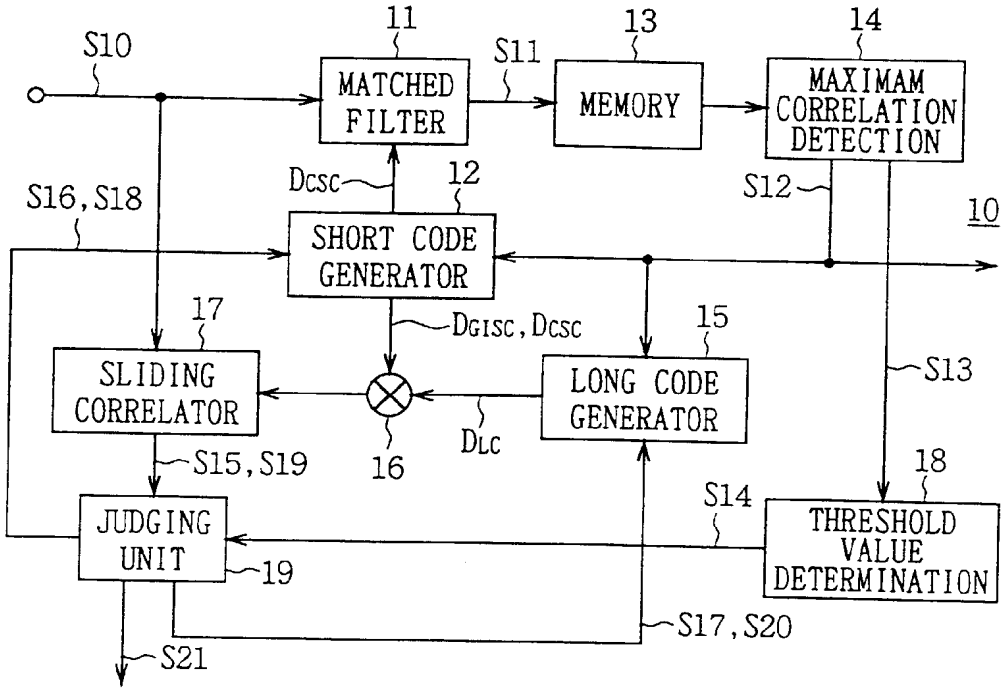


FIG. 3 (RELATED ART)

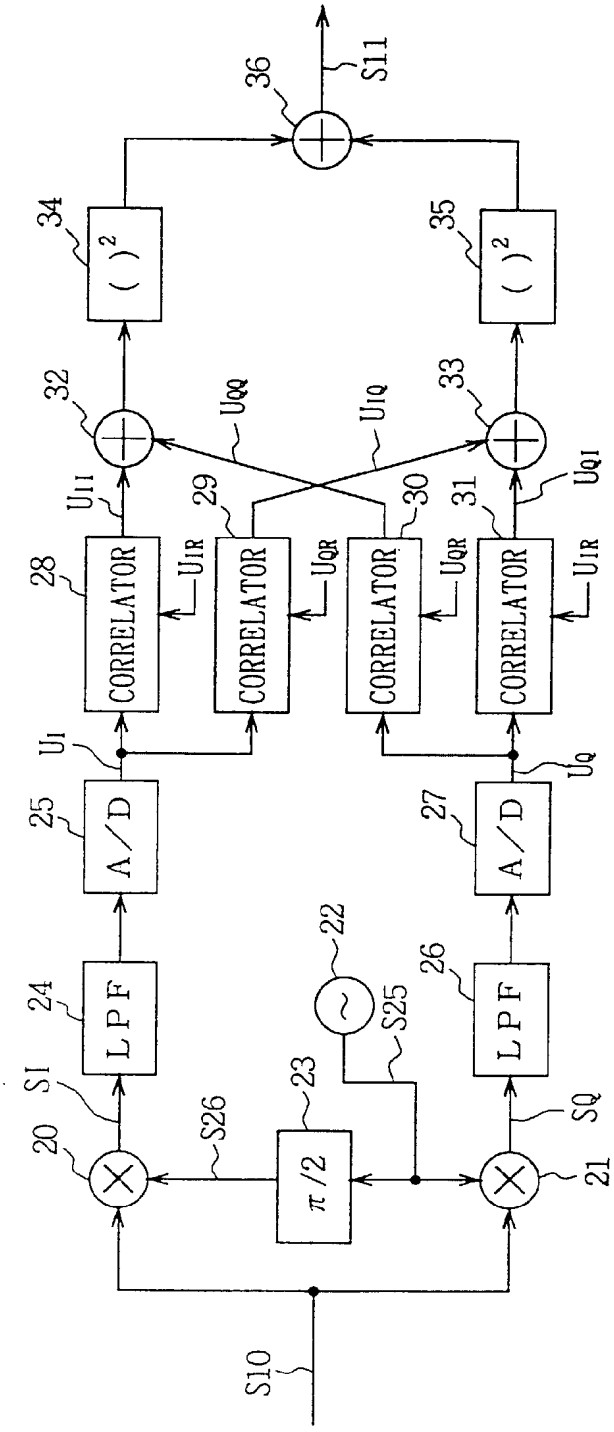


FIG. 4 (RELATED ART)

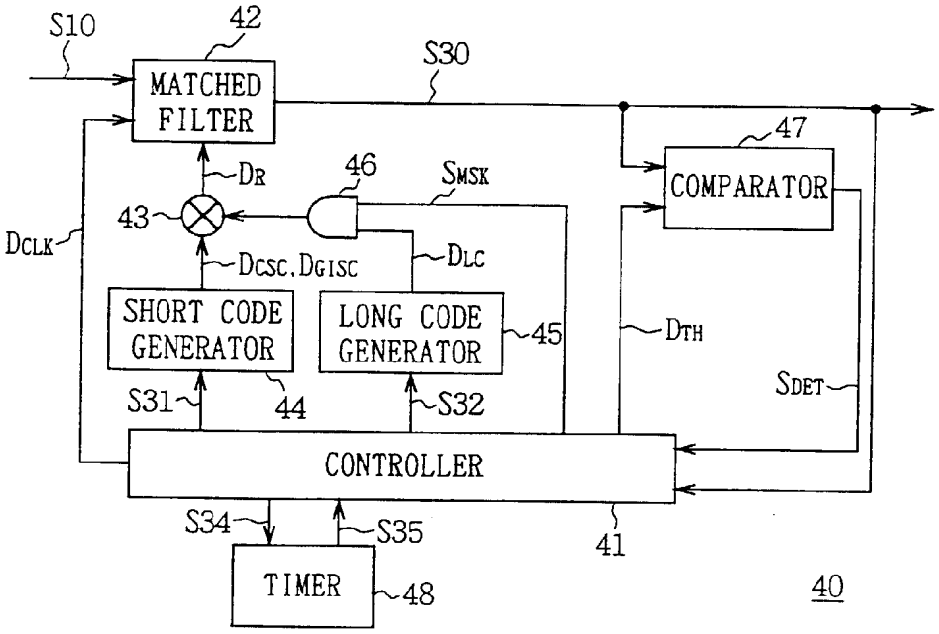

S10
42
MATCHED FILTER
S30
47
COMPARATOR
DR
46
SMSK
43
DCLK
DCSC, DGISC
DLC
SHORT CODE GENERATOR
LONG CODE GENERATOR
45
DTH
SDET
S31
44
S32
CONTROLLER
S34
S35
41
TIMER
48
40

FIG. 5

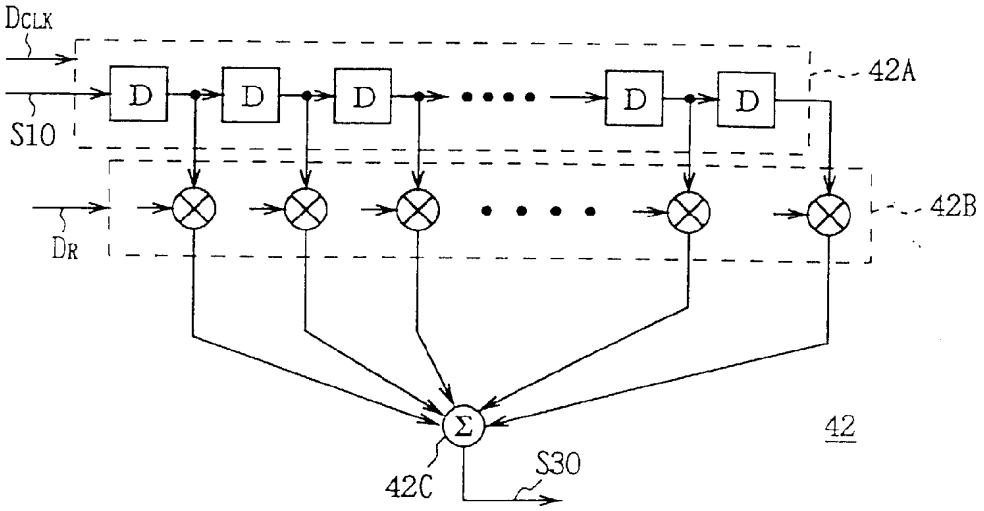

DCLK
D
D
D
D
D
42A
S10
42B
DR
Σ
42
42C
S30

FIG. 6

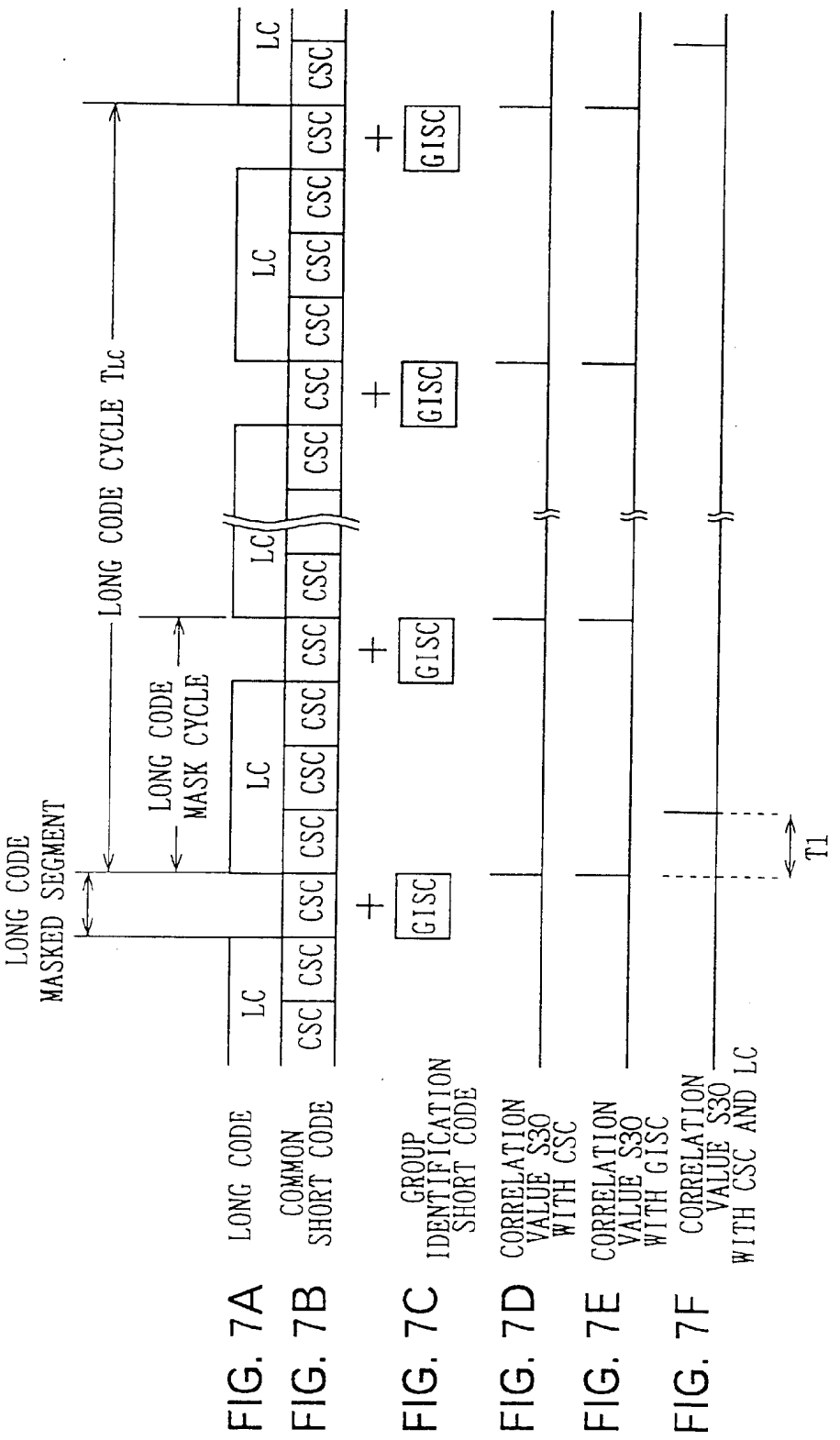


FIG. 7A LONG CODE

FIG. 7B COMMON SHORT CODE

FIG. 7C GROUP IDENTIFICATION SHORT CODE

FIG. 7D CORRELATION VALUE S3O WITH CSC

FIG. 7E CORRELATION VALUE S3O WITH GISC

FIG. 7F CORRELATION VALUE S3O WITH CSC AND LC

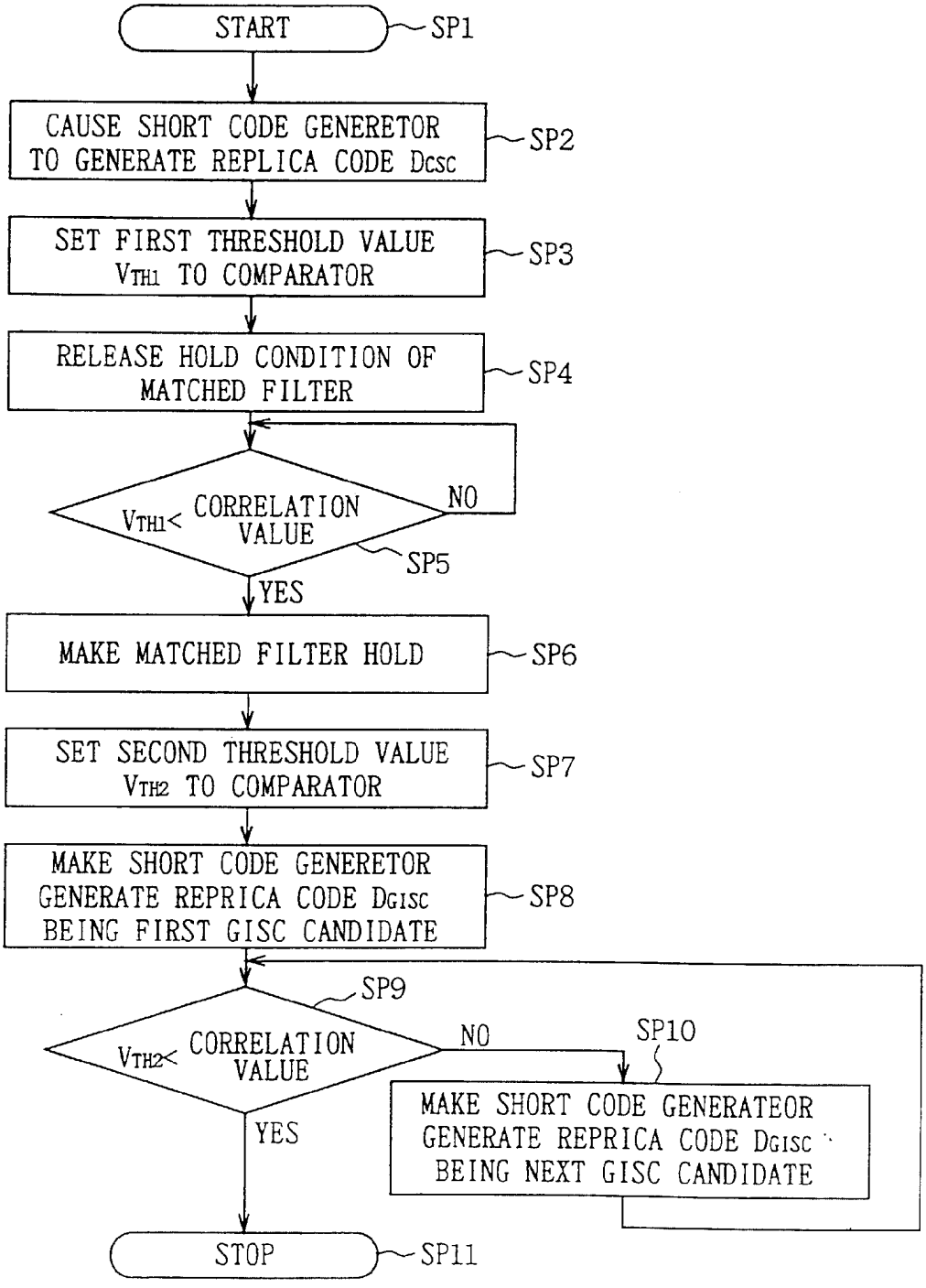

START
SP1
CAUSE SHORT CODE GENERETOR TO GENERATE REPLICA CODE Dcsc
SP2
SET FIRST THRESHOLD VALUE VTH1 TO COMPARATOR
SP3
RELEASE HOLD CONDITION OF MATCHED FILTER
SP4
VTH1< CORRELATION VALUE
NO
SP5
YES
MAKE MATCHED FILTER HOLD
SP6
SET SECOND THRESHOLD VALUE VTH2 TO COMPARATOR
SP7
MAKE SHORT CODE GENERETOR GENERATE REPRICA CODE DGISC BEING FIRST GISC CANDIDATE
SP8
SP9
VTH2< CORRELATION VALUE
NO
SP10
MAKE SHORT CODE GENERATEOR GENERATE REPRICA CODE DGISC BEING NEXT GISC CANDIDATE
YES
STOP
SP11

FIG. 8

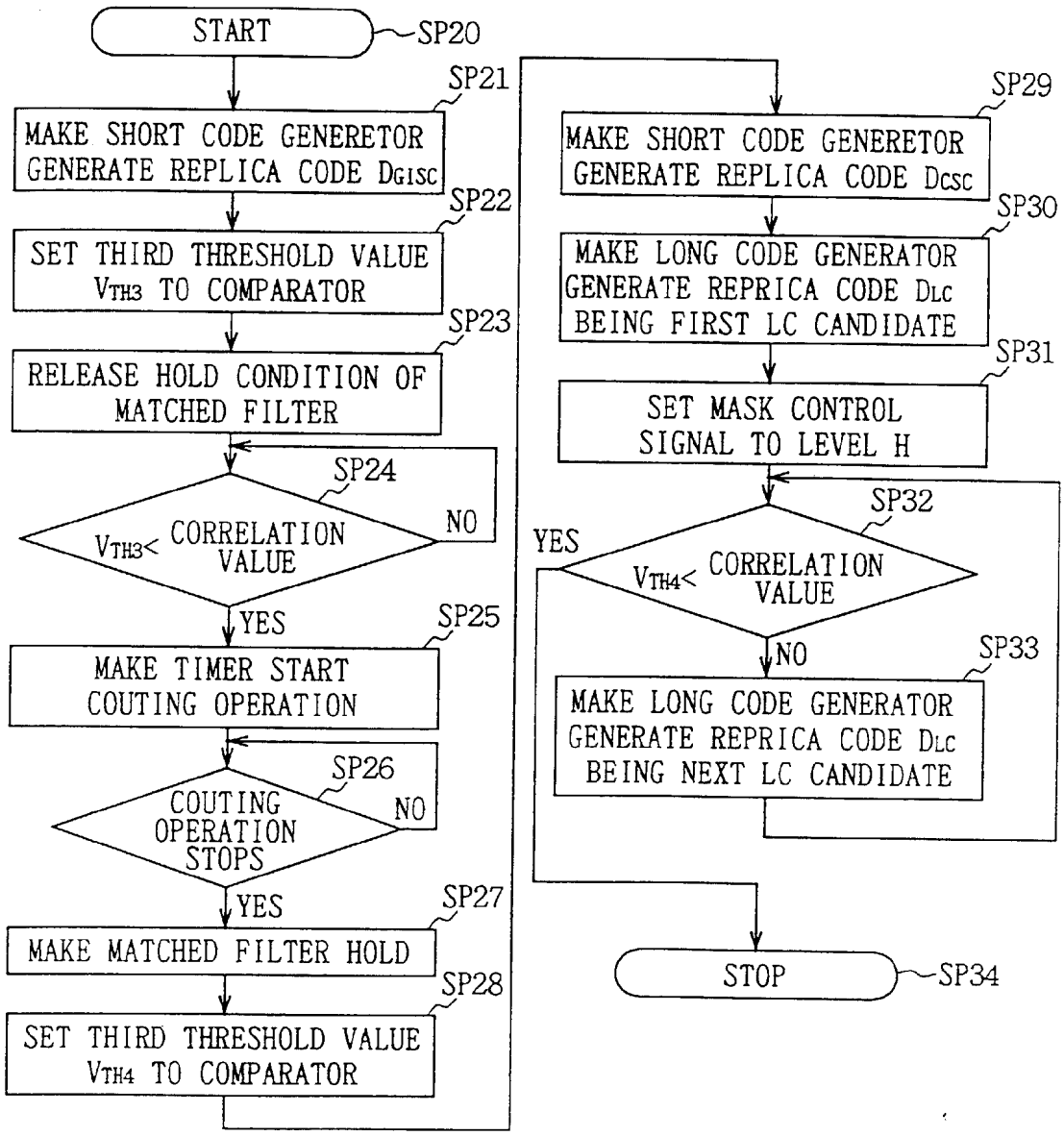

START
SP20
SP21
MAKE SHORT CODE GENERETOR GENERATE REPLICA CODE DGISC
SP22
SET THIRD THRESHOLD VALUE VTH3 TO COMPARATOR
SP23
RELEASE HOLD CONDITION OF MATCHED FILTER
SP24
VTH3< CORRELATION VALUE
NO
YES
SP25
MAKE TIMER START COUTING OPERATION
SP26
COUTING OPERATION STOPS
NO
YES
SP27
MAKE MATCHED FILTER HOLD
SP28
SET THIRD THRESHOLD VALUE VTH4 TO COMPARATOR
SP29
MAKE SHORT CODE GENERETOR GENERATE REPLICA CODE DCSC
SP30
MAKE LONG CODE GENERATOR GENERATE REPRICA CODE DLC BEING FIRST LC CANDIDATE
SP31
SET MASK CONTROL SIGNAL TO LEVEL H
SP32
YES
VTH4< CORRELATION VALUE
NO
SP33
MAKE LONG CODE GENERATOR GENERATE REPRICA CODE DLC BEING NEXT LC CANDIDATE
STOP
SP34

FIG. 9

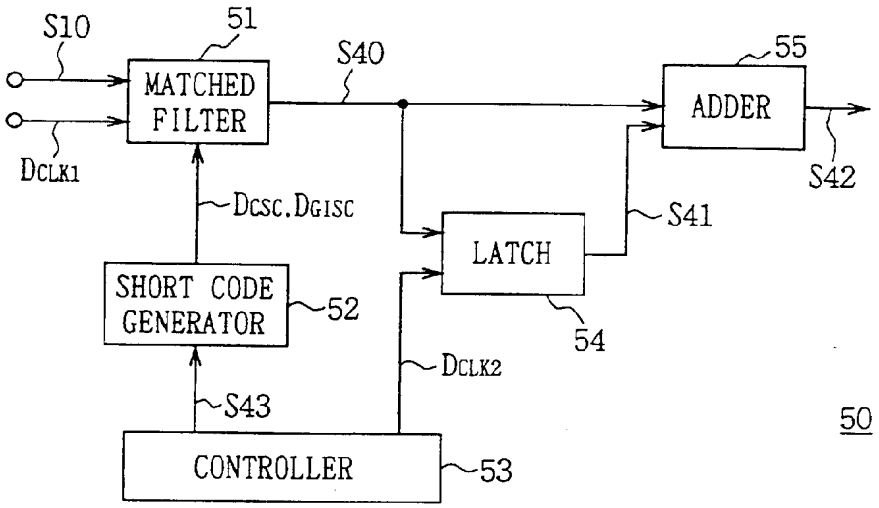

S10
51
MATCHED FILTER
S40
55
ADDER
DCLK1
S42
DCSC.DGISC
S41
LATCH
SHORT CODE GENERATOR
52
54
DCLK2
S43
50
CONTROLLER
53

FIG. 10

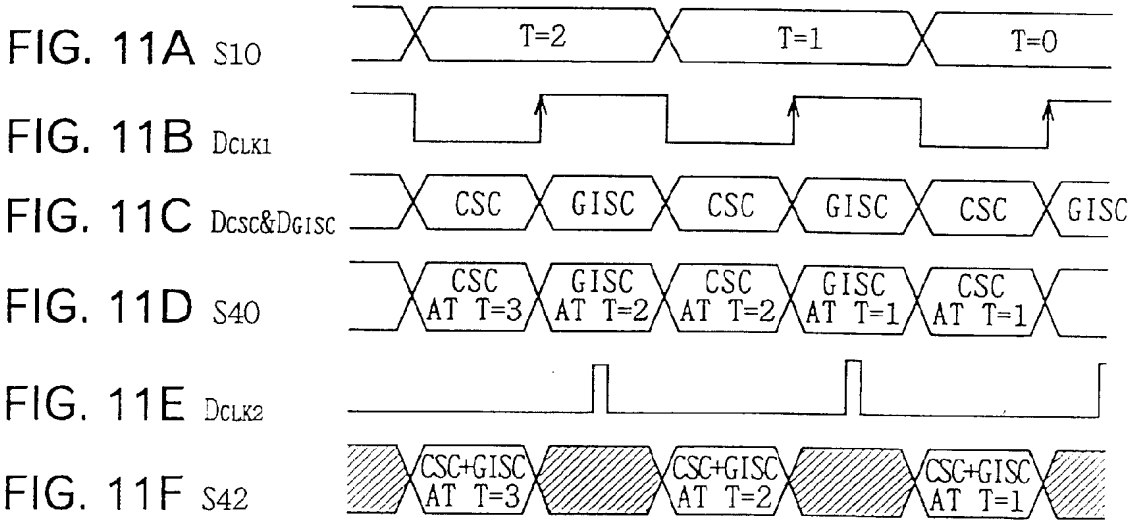


FIG. 11A S10
T=2
T=1
T=0
FIG. 11B DCLK1
FIG. 11C DCSC&DGISC
CSC
GISC
CSC
GISC
CSC
GISC
FIG. 11D S40
CSC AT T=3
GISC AT T=2
CSC AT T=2
GISC AT T=1
CSC AT T=1
FIG. 11E DCLK2
FIG. 11F S42
CSC+GISC AT T=3
CSC+GISC AT T=2
CSC+GISC AT T=1

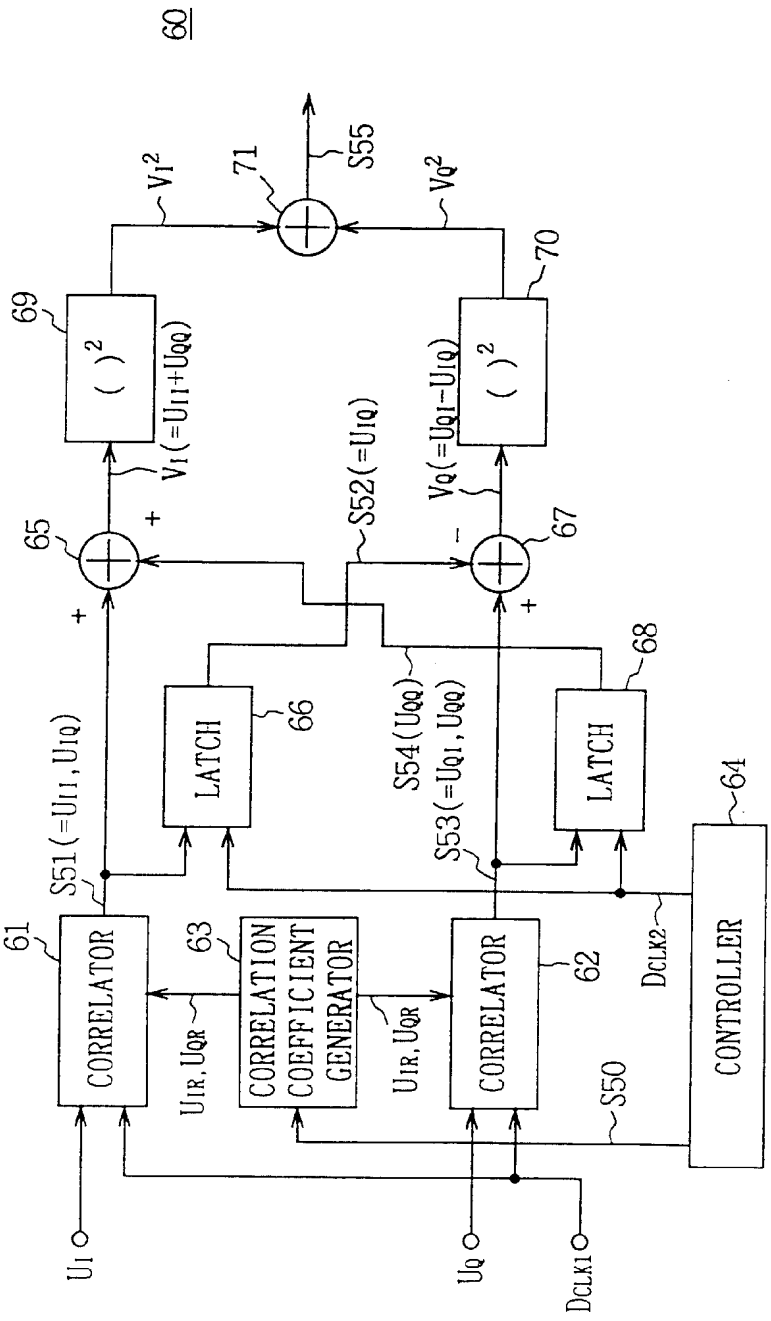

60
61
CORRELATOR
63
CORRELATION COEFFICIENT GENERATOR
62
CORRELATOR
64
CONTROLLER
66
LATCH
68
LATCH
65
67
69
( )²
70
( )²
71
S55
S50
S51(=UII, UIQ)
S52(=UIQ)
S53(=UQI, UQQ)
S54(UQQ)
VI²
VQ²
VI(=UII+UQQ)
VQ(=UQI−UIQ)
UIR, UQR
UIR, UQR
DCLK2
UI
UQ
DCLK1

FIG. 12

FIG. 13A U_I, U_Q

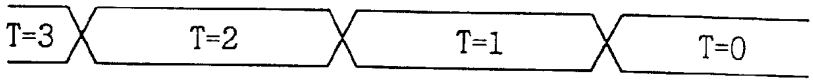


FIG. 13B D_{CLK1}

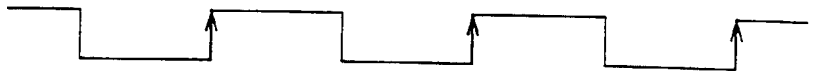


FIG. 13C U_{IR}, U_{QR}

FIG. 13D S51

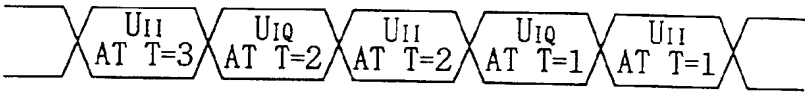


FIG. 13E S53

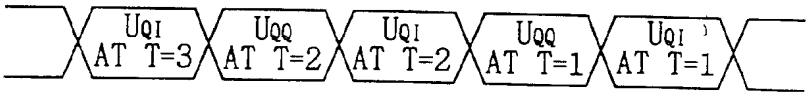


FIG. 13F D_{CLK2}

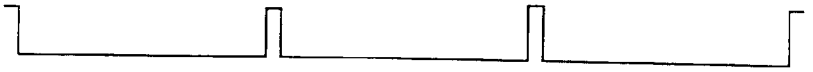


FIG. 13G V_I

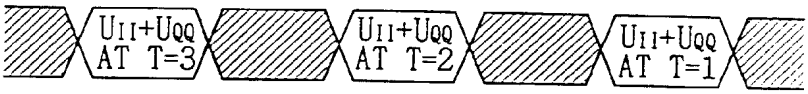


FIG. 13H V_Q

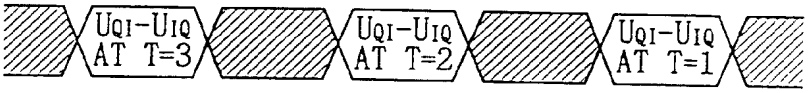
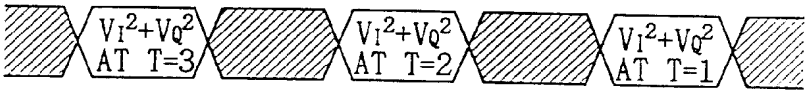


FIG. 13I S55



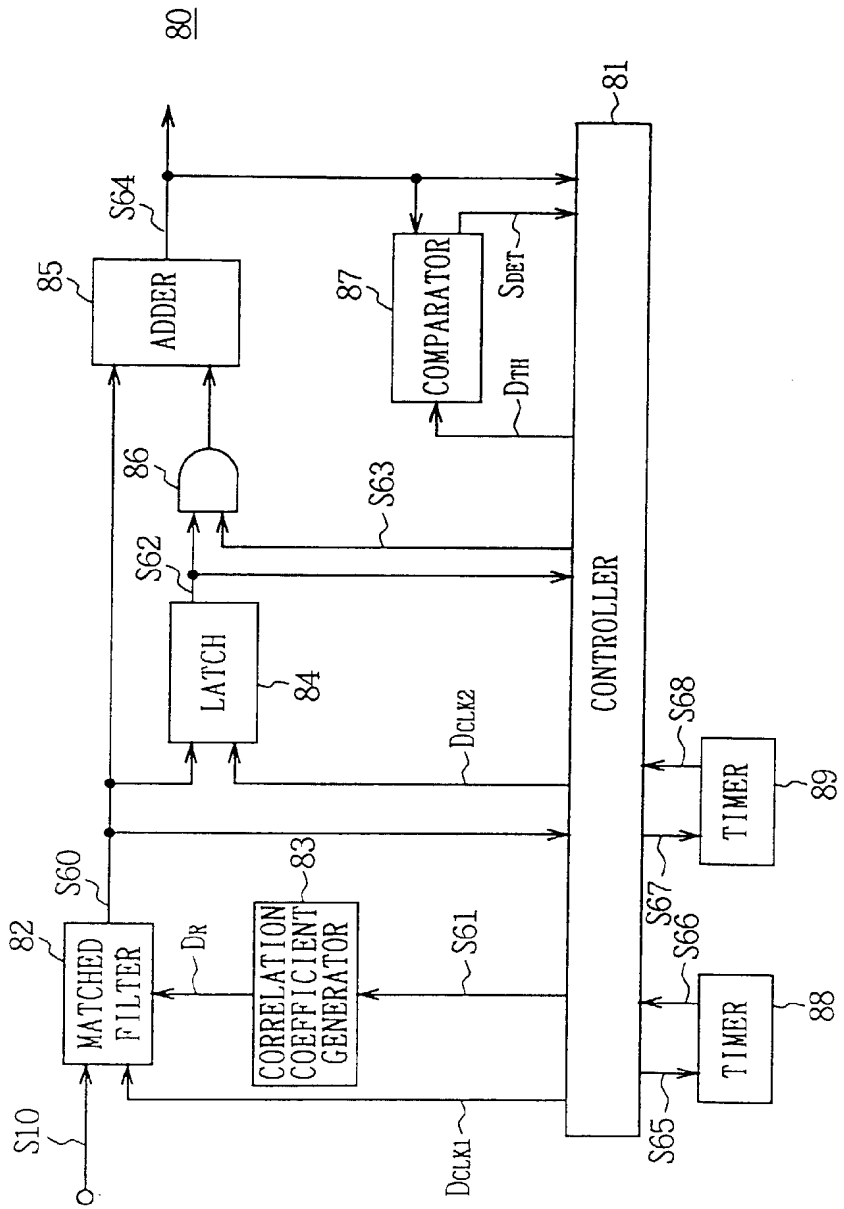

80
81
CONTROLLER
S64
85
ADDER
87
COMPARATOR
SDET
DTH
86
S63
S62
LATCH
84
DCLK2
S68
TIMER
89
S67
S66
TIMER
88
S65
S60
82
MATCHED FILTER
DR
83
CORRELATION COEFFICIENT GENERATOR
S61
S10
DCLK1

FIG. 14

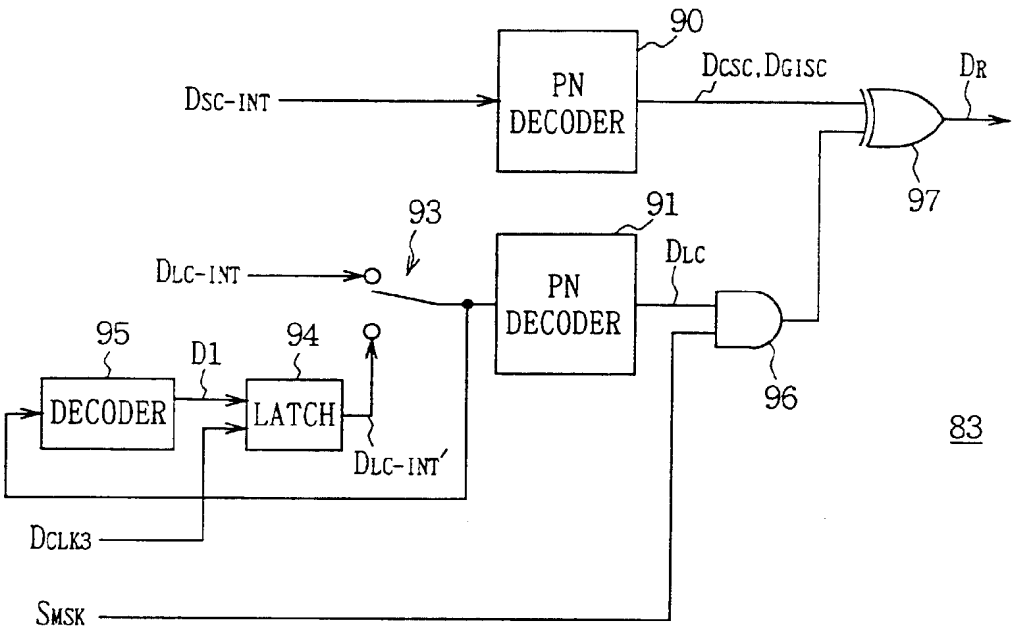

90
PN
DECODER
DSC-INT
DCSC, DGISC
DR
97
93
91
DLC-INT
PN
DECODER
DLC
95
D1
94
DECODER
LATCH
96
83
DLC-INT'
DCLK3
SMSK

FIG. 15

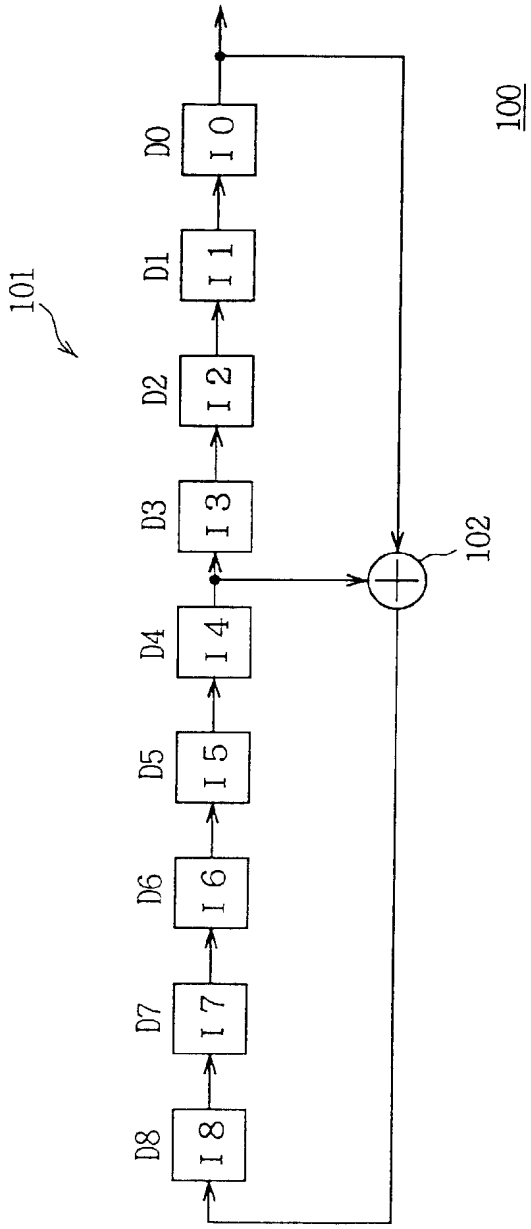


FIG. 16

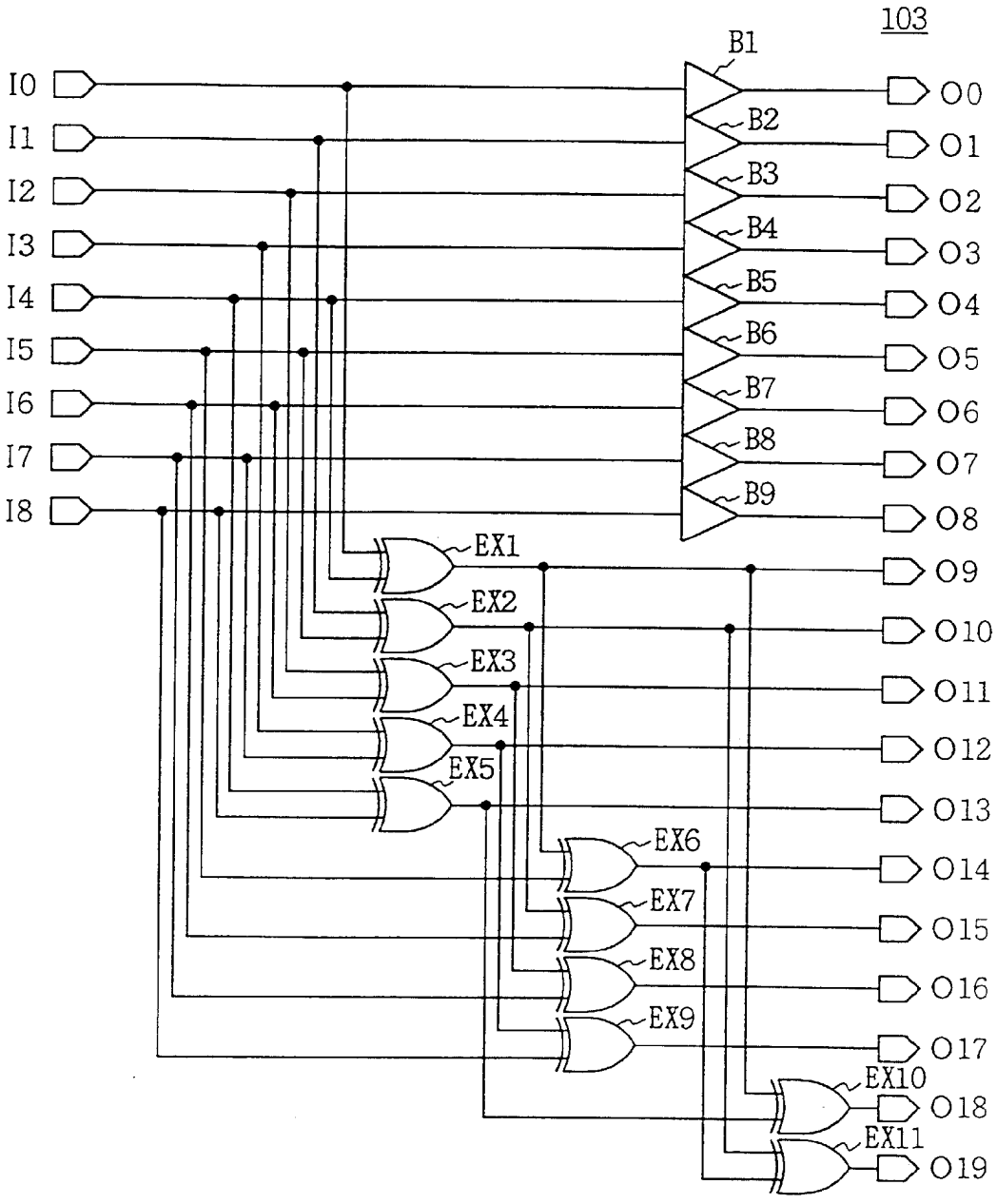

103
B1
I0
I1
I2
I3
I4
I5
I6
I7
I8
O0
O1
O2
O3
O4
O5
O6
O7
O8
B2
B3
B4
B5
B6
B7
B8
B9
EX1
EX2
EX3
EX4
EX5
EX6
EX7
EX8
EX9
EX10
EX11
O9
O10
O11
O12
O13
O14
O15
O16
O17
O18
O19

FIG. 17

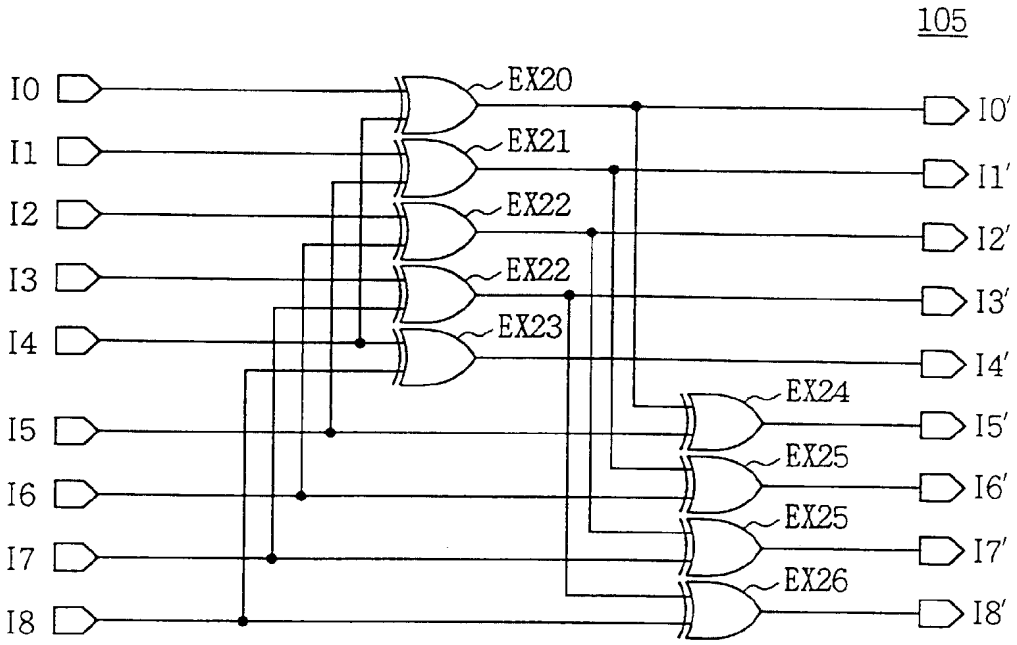

105
I0
I1
I2
I3
I4
I5
I6
I7
I8
EX20
EX21
EX22
EX22
EX23
EX24
EX25
EX25
EX26
I0'
I1'
I2'
I3'
I4'
I5'
I6'
I7'
I8'

FIG. 18

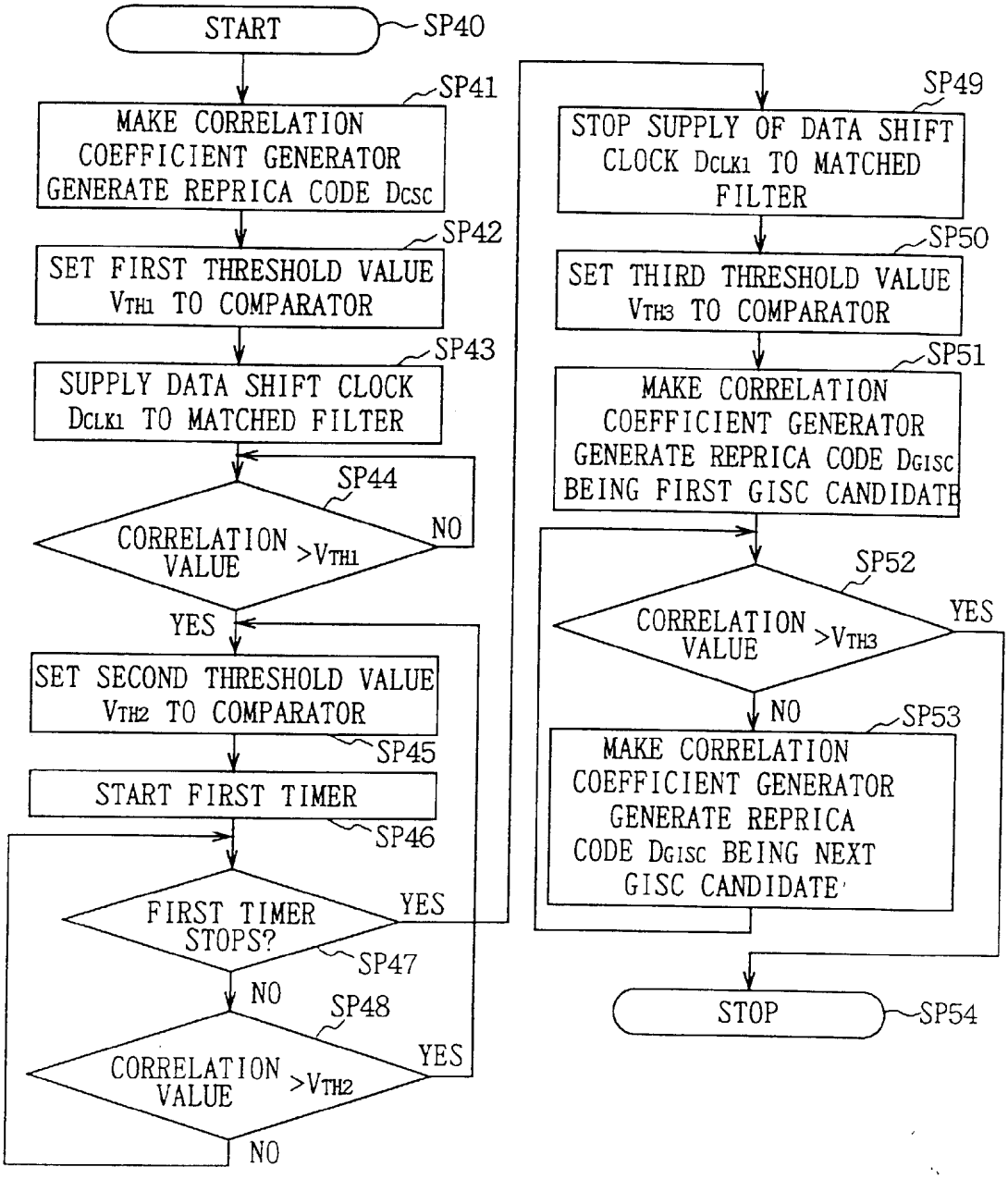

START
SP40
MAKE CORRELATION COEFFICIENT GENERATOR GENERATE REPRICA CODE DCSC
SP41
SET FIRST THRESHOLD VALUE VTH1 TO COMPARATOR
SP42
SUPPLY DATA SHIFT CLOCK DCLK1 TO MATCHED FILTER
SP43
CORRELATION VALUE >VTH1
SP44
NO
YES
SET SECOND THRESHOLD VALUE VTH2 TO COMPARATOR
SP45
START FIRST TIMER
SP46
FIRST TIMER STOPS?
YES
SP47
NO
SP48
CORRELATION VALUE >VTH2
YES
NO
STOP SUPPLY OF DATA SHIFT CLOCK DCLK1 TO MATCHED FILTER
SP49
SET THIRD THRESHOLD VALUE VTH3 TO COMPARATOR
SP50
MAKE CORRELATION COEFFICIENT GENERATOR GENERATE REPRICA CODE DGISC BEING FIRST GISC CANDIDATE
SP51
CORRELATION VALUE >VTH3
SP52
YES
NO
MAKE CORRELATION COEFFICIENT GENERATOR GENERATE REPRICA CODE DGISC BEING NEXT GISC CANDIDATE
SP53
STOP
SP54

FIG. 19

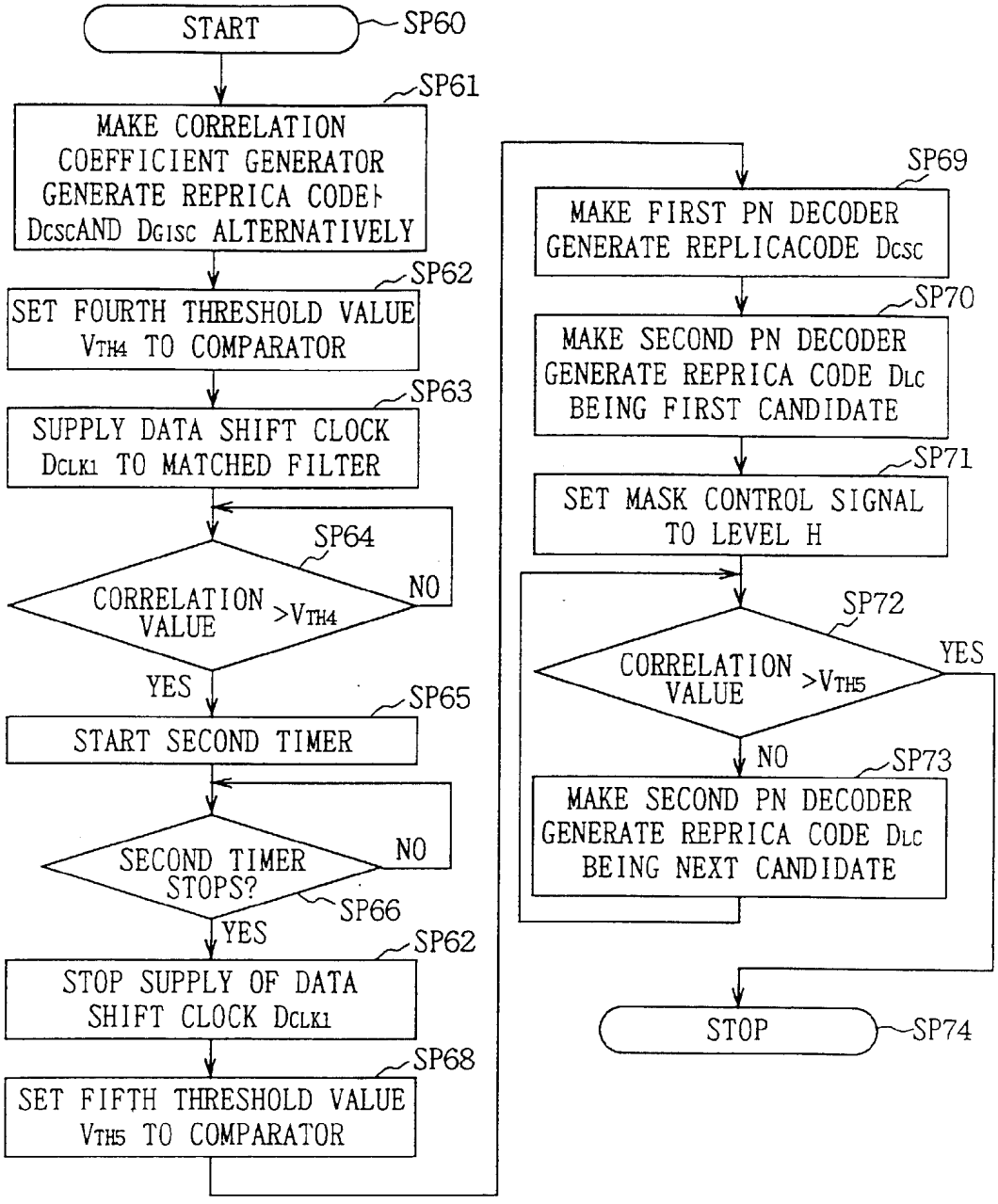

START
SP60
SP61
MAKE CORRELATION COEFFICIENT GENERATOR GENERATE REPRICA CODE Dcsc AND Dgisc ALTERNATIVELY
SP62
SET FOURTH THRESHOLD VALUE VTH4 TO COMPARATOR
SP63
SUPPLY DATA SHIFT CLOCK DCLK1 TO MATCHED FILTER
SP64
CORRELATION VALUE >VTH4
NO
YES
SP65
START SECOND TIMER
SECOND TIMER STOPS?
NO
SP66
YES
SP62
STOP SUPPLY OF DATA SHIFT CLOCK DCLK1
SP68
SET FIFTH THRESHOLD VALUE VTH5 TO COMPARATOR
SP69
MAKE FIRST PN DECODER GENERATE REPLICACODE Dcsc
SP70
MAKE SECOND PN DECODER GENERATE REPRICA CODE DLC BEING FIRST CANDIDATE
SP71
SET MASK CONTROL SIGNAL TO LEVEL H
SP72
CORRELATION VALUE >VTH5
YES
NO
SP73
MAKE SECOND PN DECODER GENERATE REPRICA CODE DLC BEING NEXT CANDIDATE
STOP
SP74

FIG. 20

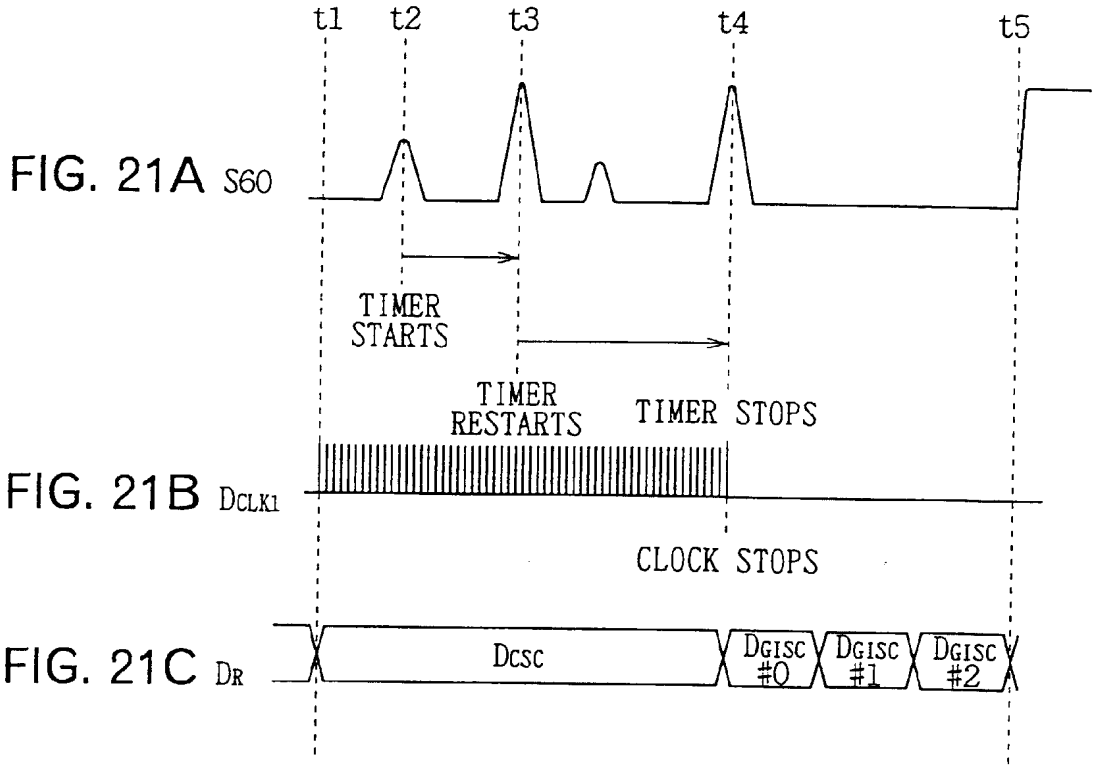


FIG. 21A S_{60}

FIG. 21B D_{CLK1}

FIG. 21C D_R